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Volume 16

TOPEX Radar Altimeter Engineering Assessment Report Update - Side B Turn-On to January 1, 2002

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About the Series

The TOPEX Radar Altimeter Technical Memorandum Series is a collection of performance assessment documents produced by the NASA Goddard Space Flight Wallops Flight Facility over a period starting before the TOPEX launch in 1992 and continuing over greater than 10 year TOPEX lifetime. Because of the mission's success over this long period and because the data are being used internationally to redefine many aspects of ocean knowledge, it is important to make a permanent record of the TOPEX radar altimeter performance assessments which were originally provided to the TOPEX project in a series of internal reports over the life of the mission. The original reports are being printed in this series without change in order to make the information more publicly available as the original investigators become less available to explain the altimeter operation and details of the various data anomalies that have been resolved.

Foreword

The Engineering Assessment of the TOPEX Radar Altimeter is performed on a continuing basis by the TOPEX Altimeter Team at NASA / GSFC Wallops Flight Facility. The Assessment Team members are:

David W. Hancock III / NASA: TOPEX Altimeter Verification Manager / Team Leader
George S. Hayne / NASA: TOPEX Altimeter Verification Manager
Craig L. Purdy / NASA: TOPEX Altimeter Development Manager
Laurence C. Rossi / NASA: TOPEX Altimeter Manager
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Jeffrey E. Lee / Raytheon ITSS
Dennis W. Lockwood / Raytheon ITSS
Ngan Tran / Raytheon ITSS
Carol T. Purdy / Raytheon ITSS

For the latest updates on the performance of the TOPEX Radar Altimeter, and for accessing many of our reports, readers are encouraged to contact our WFF / TOPEX Home Page at http: / / topex.wff.nasa.gov.

For additional information on this topic, please contact the Team Leader, David W. Hancock III. He may be reached at 757-824-1238 (Voice), 757-824-1036 (FAX), or by e-mail at hancock@osb.wff.nasa.gov.

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Section 1

Introduction

1.1 Identification of Document

This is the ninth in a series of TOPEX Radar Altimeter Engineering Assessment Reports.

The initial TOPEX Radar Altimeter Engineering Assessment Report, in February 1994, presented performance results for the NASA Radar Altimeter on the TOPEX/POSEIDON spacecraft, from the time of its launch in August 1992 to February 1994. Since the time of that initial report and prior to this report, there have been seven interim supplemental Engineering Assessment Reports, issued in March 1995, May 1996, March 1997, June 1998, August 1999, September 2000, and again in June 2001.

The sixth supplement in September 2000 was the first assessment report that addressed Side-B performance, and presented the altimeter performance from the turn-on of Side-B until the end of calendar year 1999. This report extends the performance assessment of Side B to the end of calendar year 2001.

Over the years since launch, we have performed a large variety of TOPEX performance studies; Appendix A provides an accumulative index of those studies. As the performance database has expanded, and as analysis tools and techniques continue to evolve, the longer-term trends of the altimeter data have become more apparent. The updated findings are presented here.

Section 2

On-Orbit Instrument Performance (Cycles 306 through 342)

From the time of the initial turn-on of Side B on February 10, 1999, to the end of 2001, the NASA Radar Altimeter has been in TRACK mode for a total of approximately 23,500 hours. The altimeter has been in IDLE mode for an additional 1640 hours, generally due to the French Altimeter's being turned on; the French Altimeter has not been turned on since January 23, 2001.

The NASA altimeter has been OFF for a total of 51 hours, attributable to: a 16-hour spacecraft level safehold on August 31, 1999; a related 8-hour OFF status three days later to switch the spacecraft attitude control electronics on September 3, 1999; and a 27-hour spacecraft level safehold on November 24, 2000. During 2001, the altimeter was never in OFF mode.

The succeeding sub-sections discuss:

- Side B internal calibration results
- Side B cycle-summary results
- Side B key events

2.1 Side B Internal Calibrations

The TOPEX altimeter's internal calibration mode has two submodes designated CAL-1 and CAL-2. In CAL-1 a portion of the transmitter output is fed back to the receiver through a digitally controlled calibration attenuator and delay line. The altimeter acquires and tracks this calibration signal for 10 seconds at each of 17 different preset calibration attenuator values; each calibration attenuator value is changed by 2 dB from its neighbor. The altimeter's CAL-1 has almost the same signal path as the normal fine-track mode, except that CAL-1 has a delay line, a different attenuator, and switches to select these components. The altimeter's automatic gain control (AGC) loop is active during each CAL-1 step, so changes in CAL-1 range and AGC should be directly relatable to changes in the altimeter's fine-track range and power estimation. The AGC level of CAL-1 Step 5 best represents the average level seen in normal over-ocean fine-tracking, so CAL-1 Step 5 data are used in the discussions of changes in calibration mode range and power estimates in this report.

When commanded to its calibration mode, the TOPEX altimeter first enters CAL-1 and then CAL-2. Each of the 17 steps within CAL-1 lasts about 10 seconds, and then CAL-2 lasts about a minute, so the entire calibration sequence lasts about 4 minutes. Internal altimeter calibrations are scheduled twice-per-day, over land areas, at approximately 0000 UTC and 1200 UTC. Internal calibrations are also performed whenever the NASA altimeter is commanded from TRACK to IDLE for a period of tracking by the French altimeter, or from IDLE back to TRACK when tracking resumes for the NASA altimeter. The calibrations prior to and after the French altimeter operations are not constrained to land areas, and usually occur over open ocean.

Our processing of the CAL-1 range data was modified in 1994, to remove the effect of the 7.3 mm quantization; the revised method is discussed in Section 2.1.1 (page 2) of the year 1994 supplement (published in March 1995). All the calibration data since launch have been processed using the revised method.

2.1.1 Range Calibrations

The change in Ku-Band range, from Side B turn-on on day 042 of 1999 to the end of 2001, is plotted in Figure 2-1 "Ku-Band Range CAL-1 Results" on page 2-3. CAL-1 steps 4 through 7 are shown in the figure. The Ku-Band delta range shown in Figure 2-1 (and in the succeeding calibration plots) is calculated based on the measurement minus a reference. This calibration range plot indicates that the Side B Ku-Band delta range has varied only about +1 mm from the time of its turn-on to the end of 2001.

The change in C-Band calibration range is depicted in Figure 2-2 "C-Band Range CAL-1 Results" on page 2-4. This plot indicates that, during the initial 200 days after turn-on, the Side B C-Band range negatively drifted (i.e., became shorter) by about 8 mm. Since that time, to the end of 2001, there has been a negative drift of approximately 2 mm.

Range calibrations and their correction values are discussed in more detail in Section 3.1.

2.1.2 AGC Calibrations

2.1.2.1 CAL-1 and CAL-2

The change in Side B Ku-Band AGC since launch is shown in Figure 2-3 "Ku-Band AGC CAL-1 and CAL-2 Results" on page 2-5. CAL-1 steps 4 through 6, plus CAL-2, are depicted in the figure. At approximately 210 days after turn-on, there was an apparent step-function change as the Ku AGC increased approximately 0.2 dB. Since the time of that occurrence, the Ku AGC gradually increased another 0.1 dB.

The change in C-Band AGC since Side B turn-on is shown in Figure 2-4 "C-Band AGC CAL-1 and CAL-2 Results" on page 2-6. The Side B AGC has remained at essentially the same level (+0.1 dB) since turn-on.

A more in-depth analysis of the AGC calibrations is presented in Section 3.2.

2.2 Side B Cycle Summaries

The data in the Side B cycle summary plots which follow are extracted from the Geophysical Data Record (GDR) database at WFF. The criteria for TOPEX GDR measurements to be accepted for the WFF database are: 1) the data are classified as Deep Water, 2) the data are in normal Track Mode, and 3) selected data quality flags are not set.

For each measurement type, the plots contain one averaged measurement per cycle. The cycle average value is itself the mean of one-minute along-track boxcar averages,

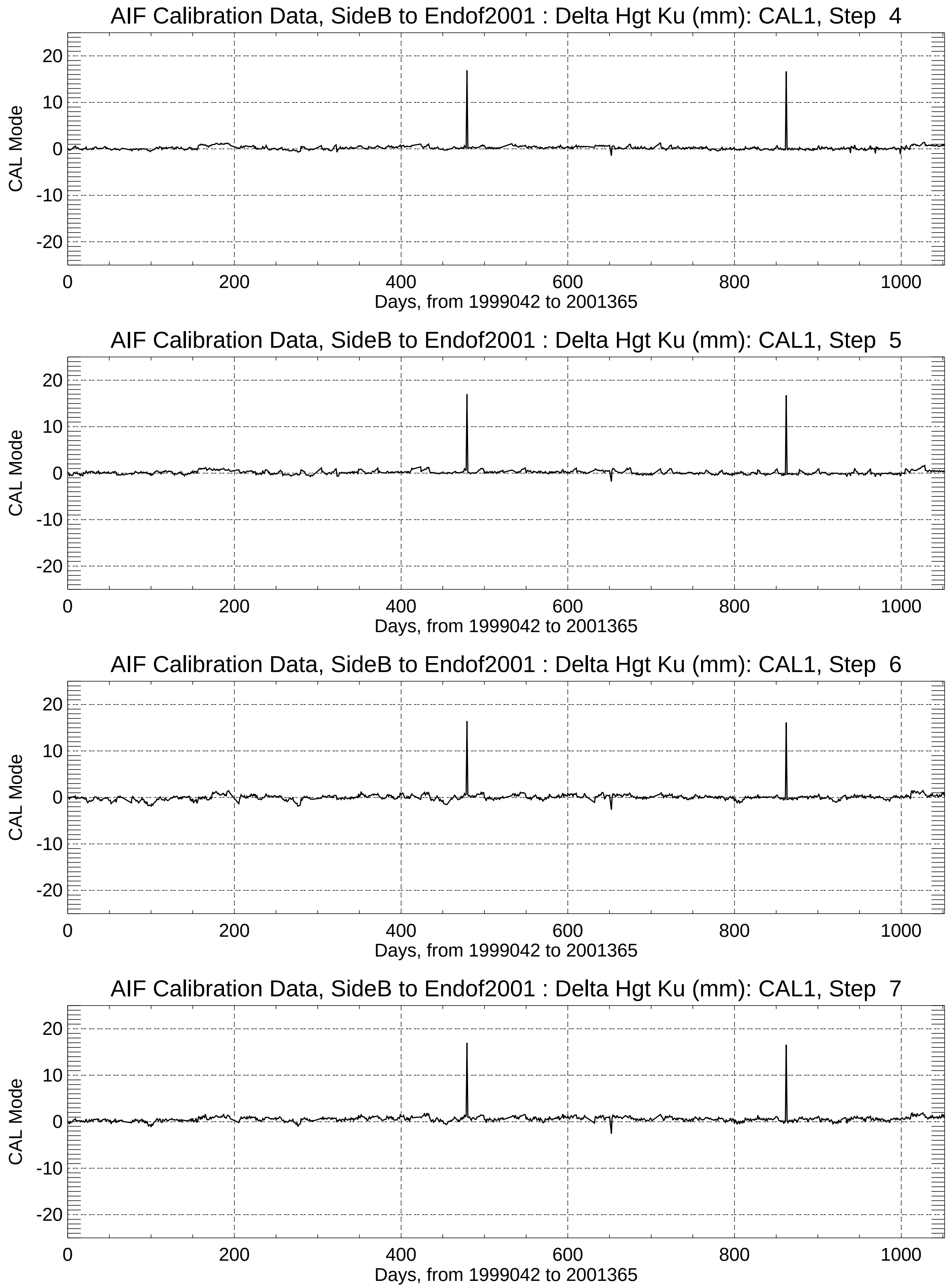


Figure 2-1 Ku-Band Range CAL-1 Results

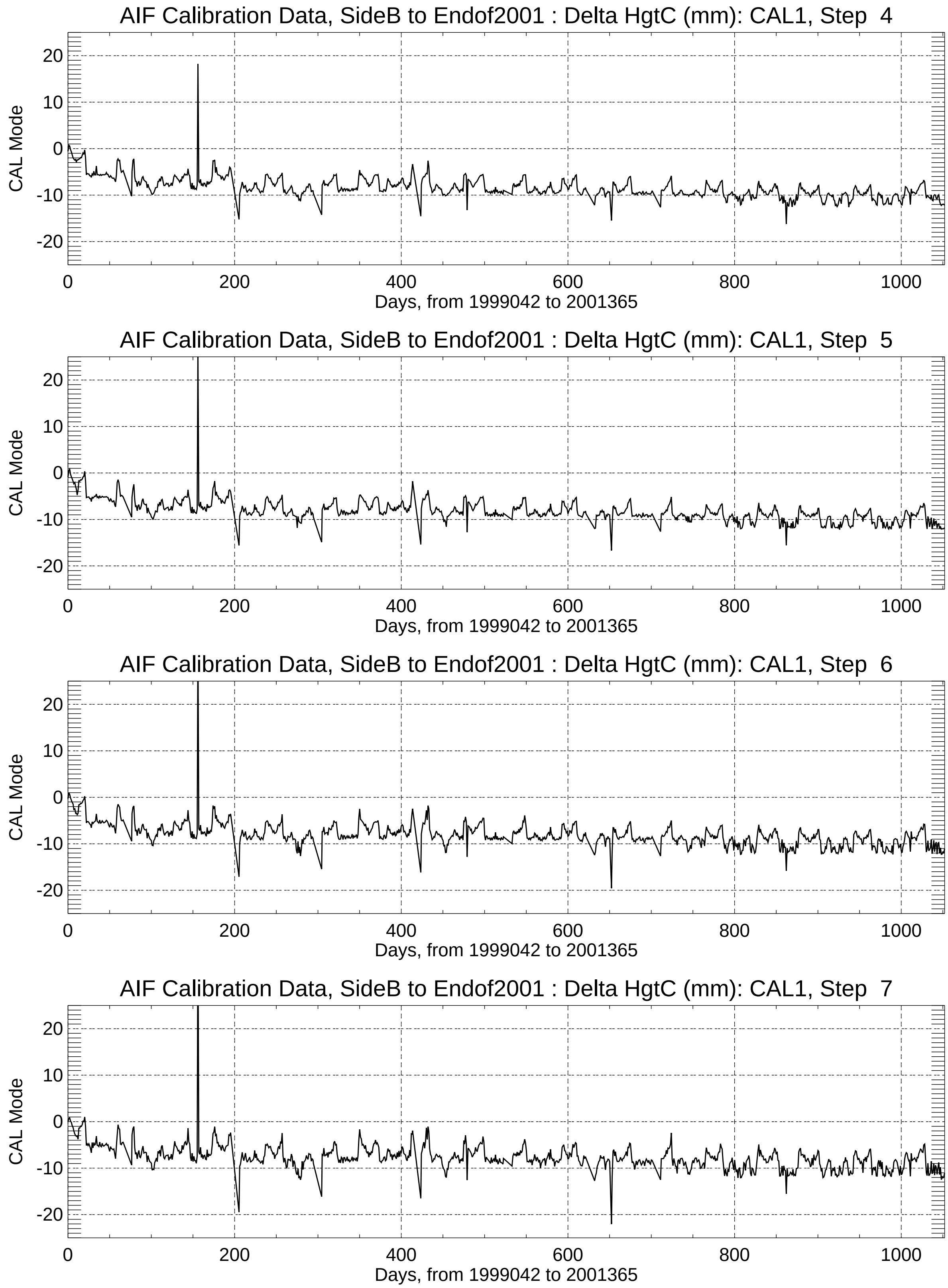


Figure 2-2 C-Band Range CAL-1 Results

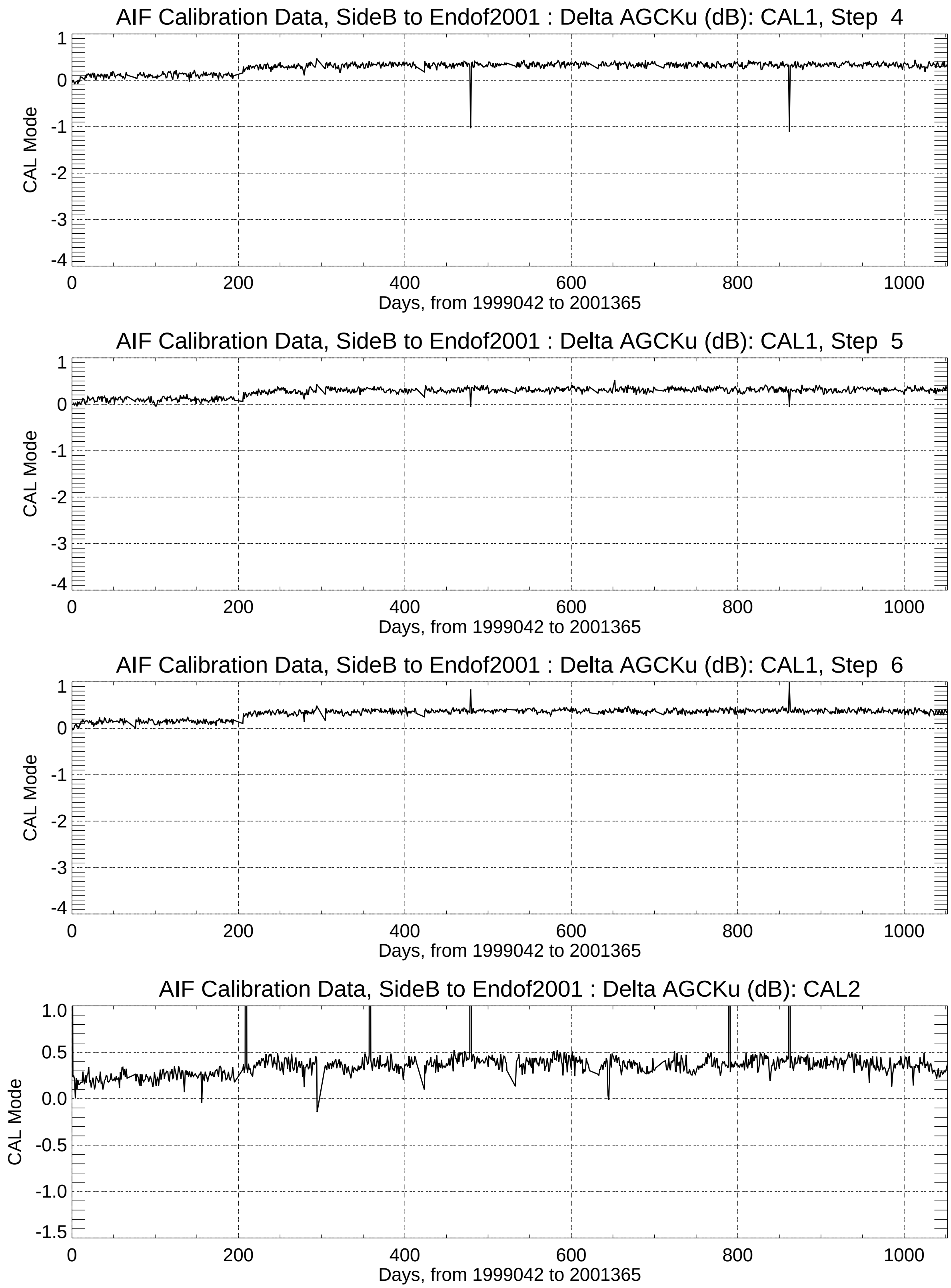


Figure 2-3 Ku-Band AGC CAL-1 and CAL-2 Results

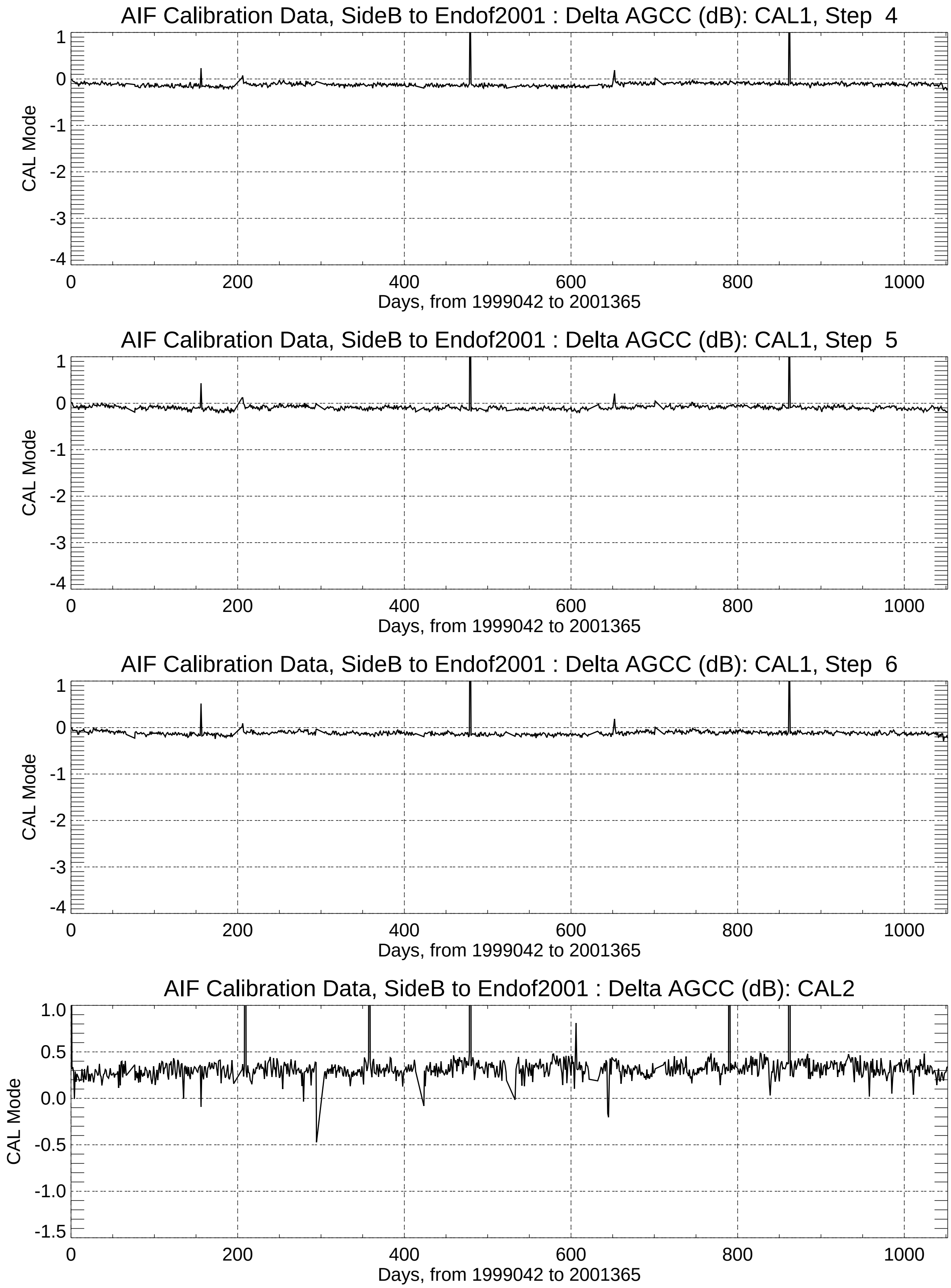


Figure 2-4 C-Band AGC CAL-1 and CAL-2 Results

after editing. Data are excluded from the averaging process whenever the one-minute-averaged off-nadir angle exceeds 0.12 degree or the averaged Ku-Band sigma0 exceeds 16 dB or whenever the number of non-flagged frames within the one-minute interval is fewer than 45. These edit criteria primarily have to do with eliminating the effects of sigma0 blooms. As a result of this edit, approximately 15% of the database measurements are excluded from the averaging process. This tight editing is part of our effort to ensure that anomalous data are excluded from the performance assessment process.

2.2.1 Sea Surface Height

The sea surface heights (ssh) contained in the GDR files are based on combined heights. Cycle-average ssh are shown in Figure 2-5 "Cycle-Average Sea Surface Height in Meters". It is not possible to discern range drifts at the millimeter level from these data, but seasonal variations of global sea level are observable. [There are 36.8 cycles per year.]

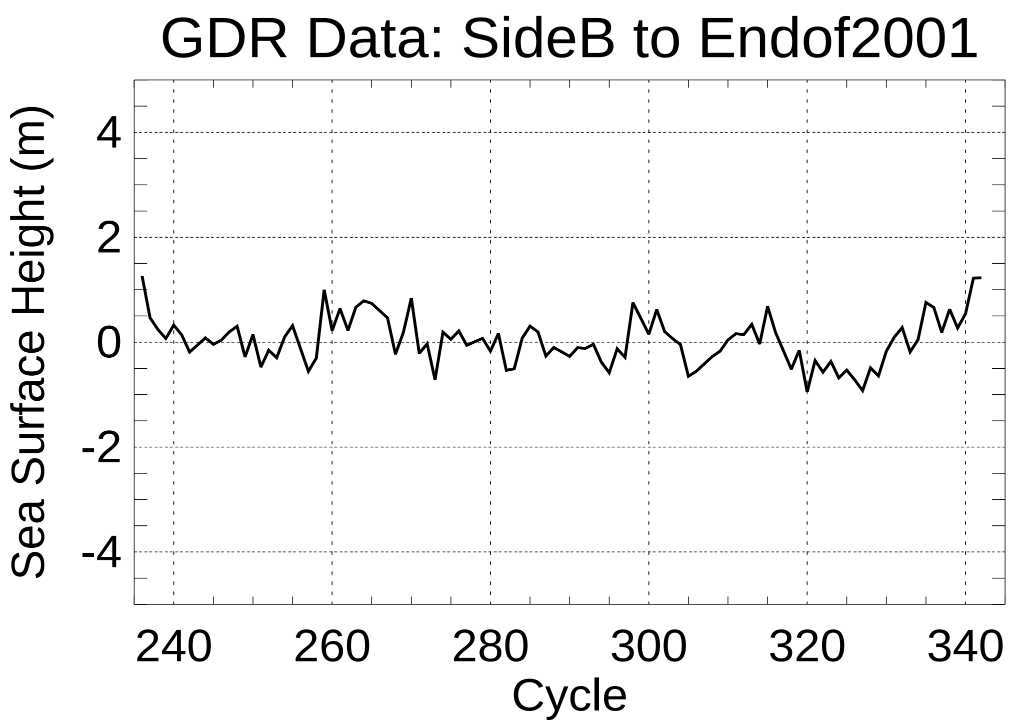


Figure 2-5 Cycle-Average Sea Surface Height in Meters

2.2.2 Sigma0

The sigma0 cycle-averages are plotted in Figure 2-6 "Cycle-Average Ku-Band Sigma0 in dB" and Figure 2-7 "Cycle-Average C-Band Sigma0 in dB" on page 2-8 for Ku-Band and C-Band, respectively. The Ku-Band sigma0 has generally remained in a band between 10.95 and 11.30 dB, while the C-Band has been in a band between 14.40 and 14.80 dB.

Sigma0 trends are discussed in more detail in Section 3.2.

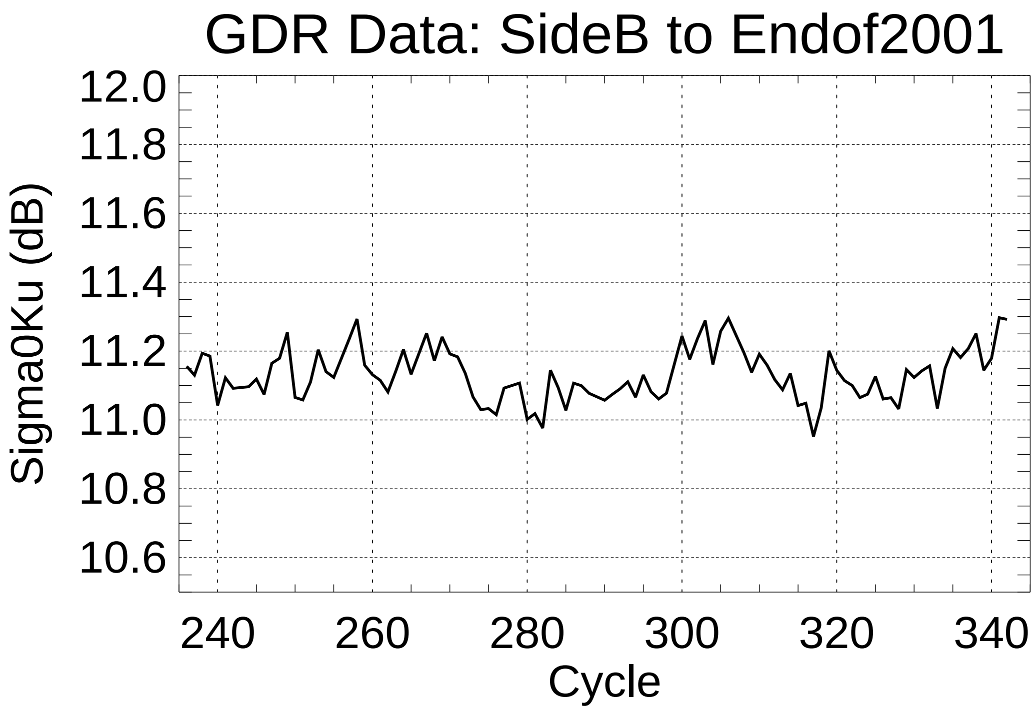


Figure 2-6 Cycle-Average Ku-Band Sigma0 in dB

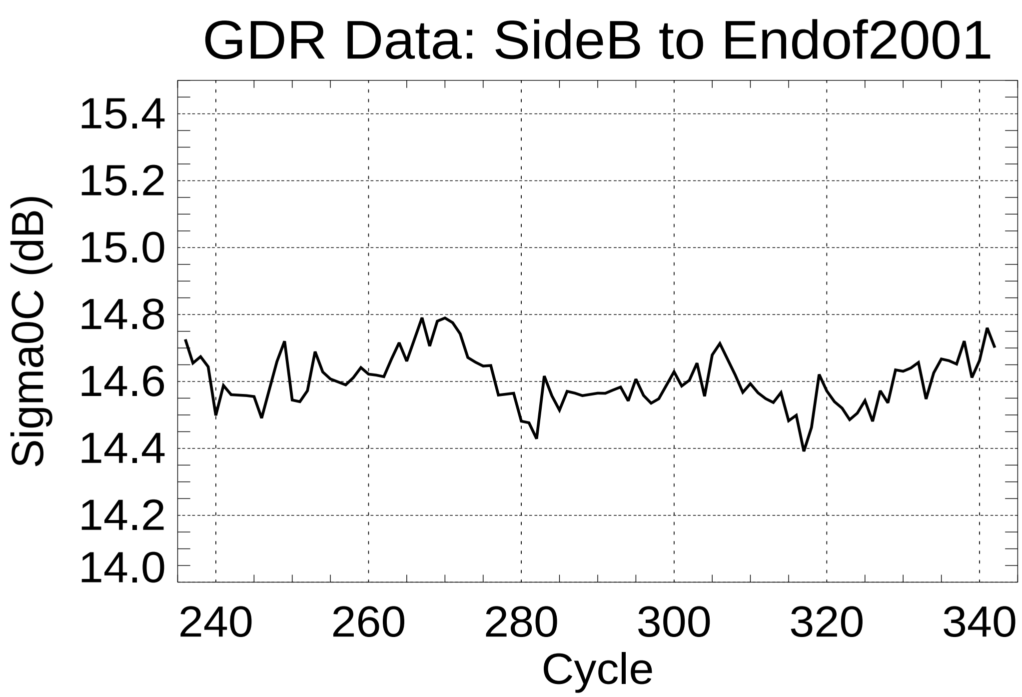


Figure 2-7 Cycle-Average C-Band Sigma0 in dB

2.2.3 Significant Wave Height

Ku-Band cycle-averages for significant wave height (SWH) are shown in Figure 2-8 "Cycle-Average Ku-Band Significant Wave Height in Meters" and C-Band cycle-averages for significant wave height (SWH) are shown in Figure 2-9 "Cycle-Average C-Band Significant Wave Height in Meters". Seasonal trends in SWH are observable.

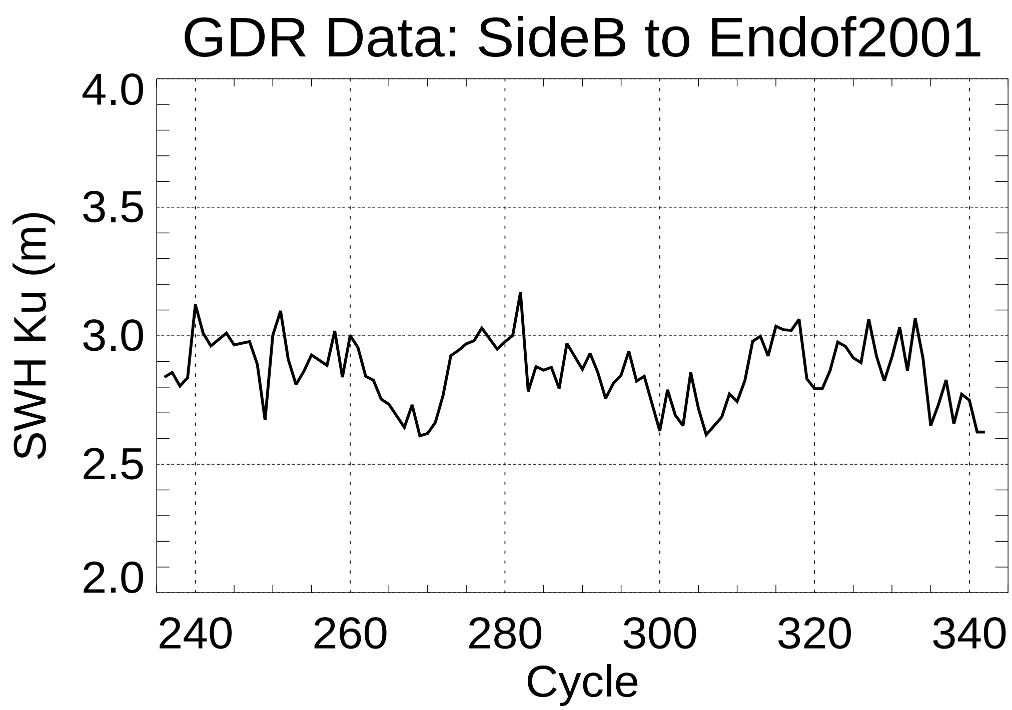


Figure 2-8 Cycle-Average Ku-Band Significant Wave Height in Meters

2.2.4 Range RMS

The calculated Ku-Band range rms values depicted in Figure 2-10 "Cycle-Average Ku-Band Range RMS in Millimeters" on page 2-11 are based on the rms derivation described in Section 5.1.1 of the February 1994 Engineering Assessment Report. An expected correlation with SWH is apparent.

2.2.5 Waveform Monitoring

Selected telemetered waveform gates during CAL-2 and STANDBY modes are monitored daily, to discern waveform changes throughout the mission. CAL-2 waveform sets are generally available twice per day, during calibrations. STANDBY waveforms are generally available four times per day, since the altimeter passes through STANDBY mode just prior to and immediately after each CALIBRATE mode. The relationship of telemetered waveform sample numbers to the onboard waveform-sample numbers is listed in Table 6.2.1 of the February 1994 Engineering Assessment Report.

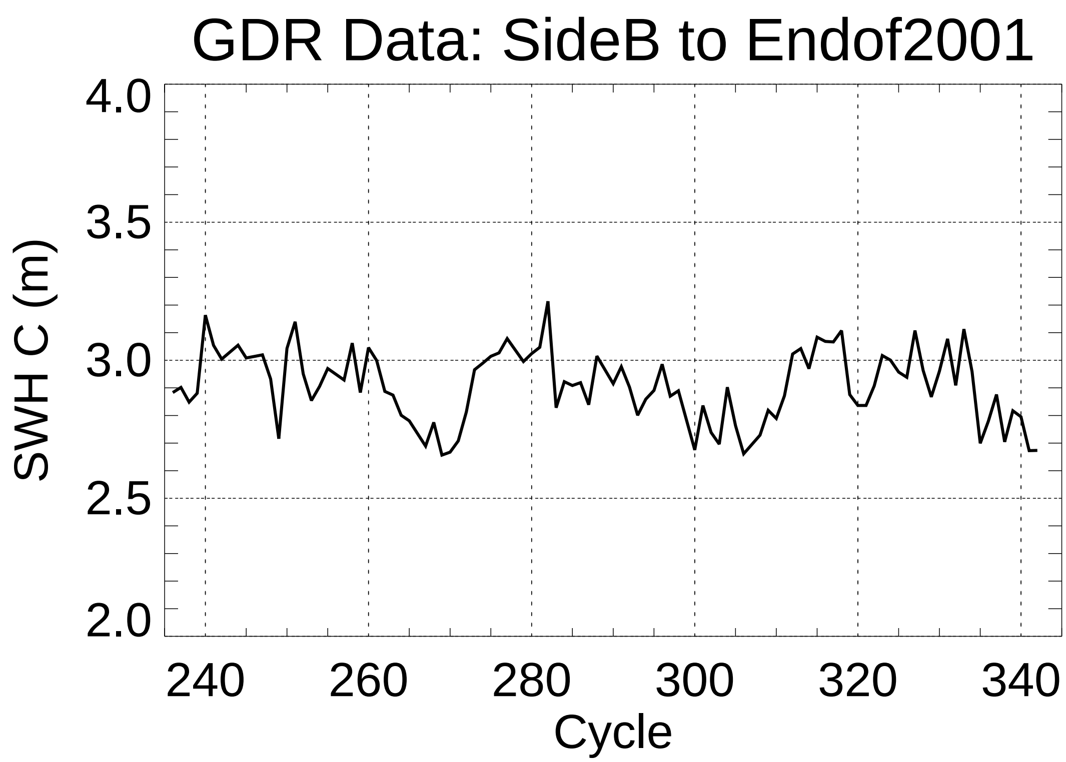


Figure 2-9 Cycle-Average C-Band Significant Wave Height in Meters

For both Ku-Band and C-Band, the monitored waveform samples are as follows: CAL-2 gates 23, 29, 48, and 93; and STANDBY gates 38, 39, 68, and 69. The Ku-Band waveform sample history is shown in Figure 2-11 "Ku-Band CAL-2 Waveform Sample History" on page 2-12 and in Figure 2-12 "Ku-Band STANDBY Waveform Sample History" on page 2-13for CAL-2 and STANDBY, respectively. The C-Band waveform history is depicted in Figure 2-13 "C-Band CAL-2 Waveform Sample History" on page 2-14 and in Figure 2-14 "C-Band STANDBY Waveform Sample History" on page 2-15, respectively, for CAL-2 and STANDBY.

The monitored Ku-Band CAL-2 waveform samples for Sides B in Figure 2-11 have each varied less than 1% throughout the mission, and exhibit little or no temperature dependence.

The Ku-Band STANDBY waveform samples in Figure 2-12, in contrast, have a slight inverse dependence on temperature (launch-to-date temperatures are shown in Figure 2-15 on the same horizontal time scale as the waveform samples). From the time of Side B turn-on, each of the four sampled gates quickly increased between 5% and 20%, and has then remained fairly steady. Gate 69 is decreasing slightly.

The Side B C-Band CAL-2 waveforms samples, shown in Figure 2-13, are similar to the Ku-Band CAL-2 waveforms in that they have varied less than about 1%, and exhibit no apparent temperature dependence. They differ from Ku-Band, however, in that there are small C-Band changes in amplitude, commencing near the beginning of the year 2001 (around day 685 in the figure); Gates 23 and 93 have both decreased in

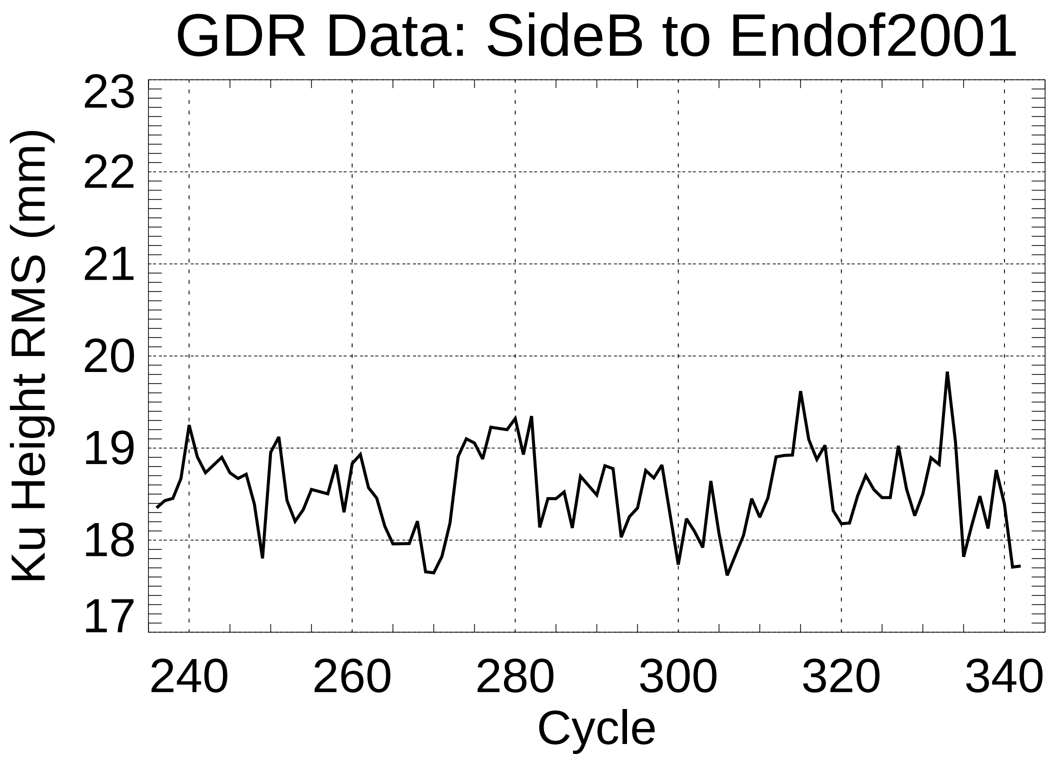


Figure 2-10 Cycle-Average Ku-Band Range RMS in Millimeters

amplitude by about 0.3%. Gates 29 and 48 have increased in amplitude approximately 0.5% and 0.3%, respectively. All four gates show decreased variability after day 685. The cause of these waveform changes is not understood at this time.

The C-Band STANDBY waveform samples, shown in Figure 2-14, are similar to their counterpart Ku-Band STANDBY waveforms in that Gates 38, 39, 68, and 69 have an inverse dependence on temperature, and have each experienced increases shortly after turn-on. Similar to the C-Band CAL-2 waveforms, however, there are changes in the C-Band STANDBY waveforms beginning around day 685. Gate 38 exhibits reduced variability after day 685, while the amplitudes for gates 39, 68, and 69 show increases of approximately 10%, 10%, and 5%, respectively. The cause of these waveform changes is not understood at this time.

In Figure 2-13, "C-Band CAL-2 Waveform Samples", there are waveform spikes at the labeled days of 210, 359 and 480. The reasons for these spikes are posted in the "Side B Key Events", section 2.3, Table 2-2. They are: Day 210 - 1999/252, Digital Filter Bank Calibration; Day 359 - 2000/036, Digital Filter Bank Calibration; Day 480 - 2000/157, Improper SEU recovery from a Digital Filter Bank Interface Lockup.

2.2.6 Engineering Monitors

Altimeter temperatures, voltages, powers and currents continue to be monitored. The system remains very stable, with no significant changes since Side B turn-on. The engineering monitor plots presented in this section contain data based on 24-hour

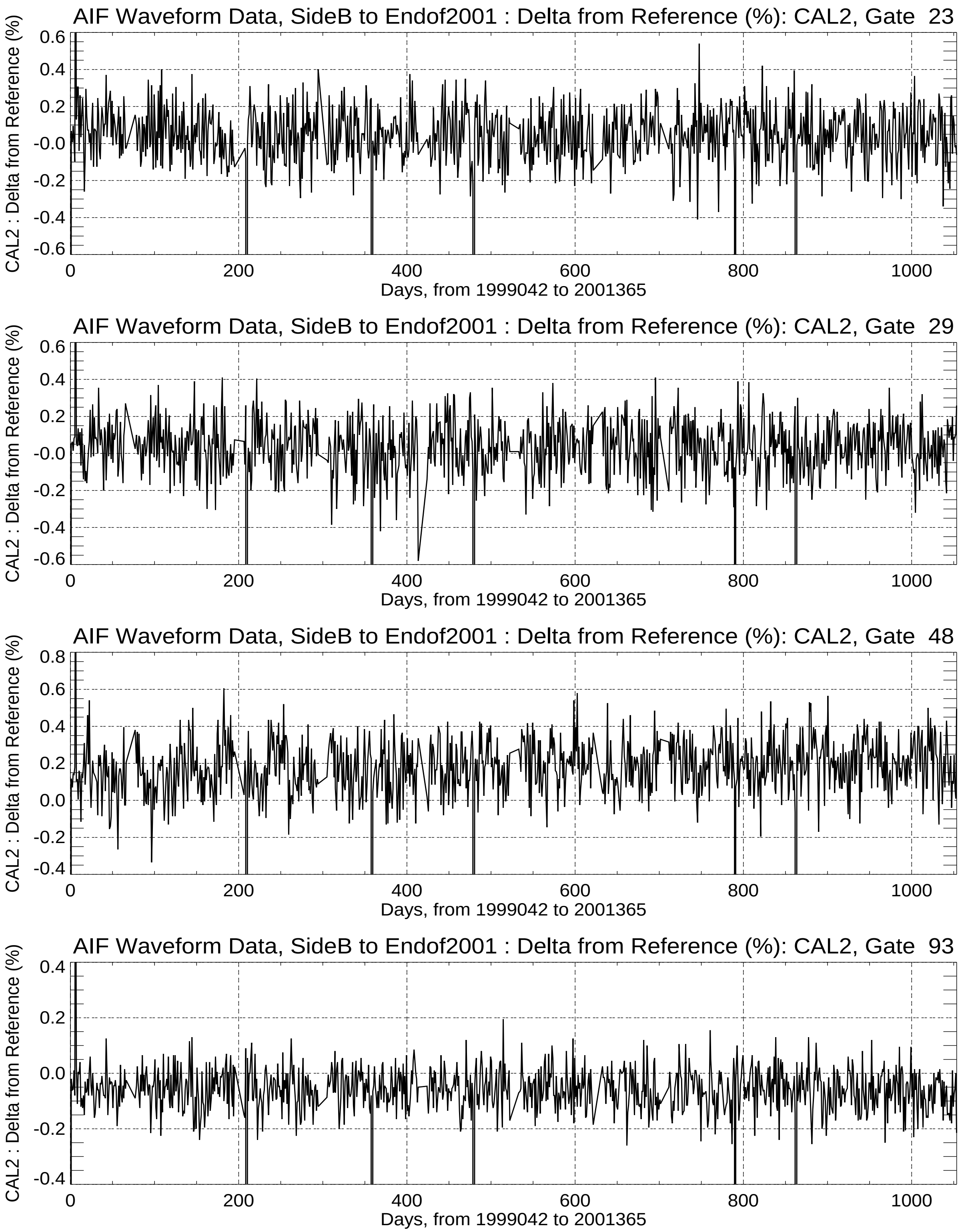


Figure 2-11 Ku-Band CAL-2 Waveform Sample History

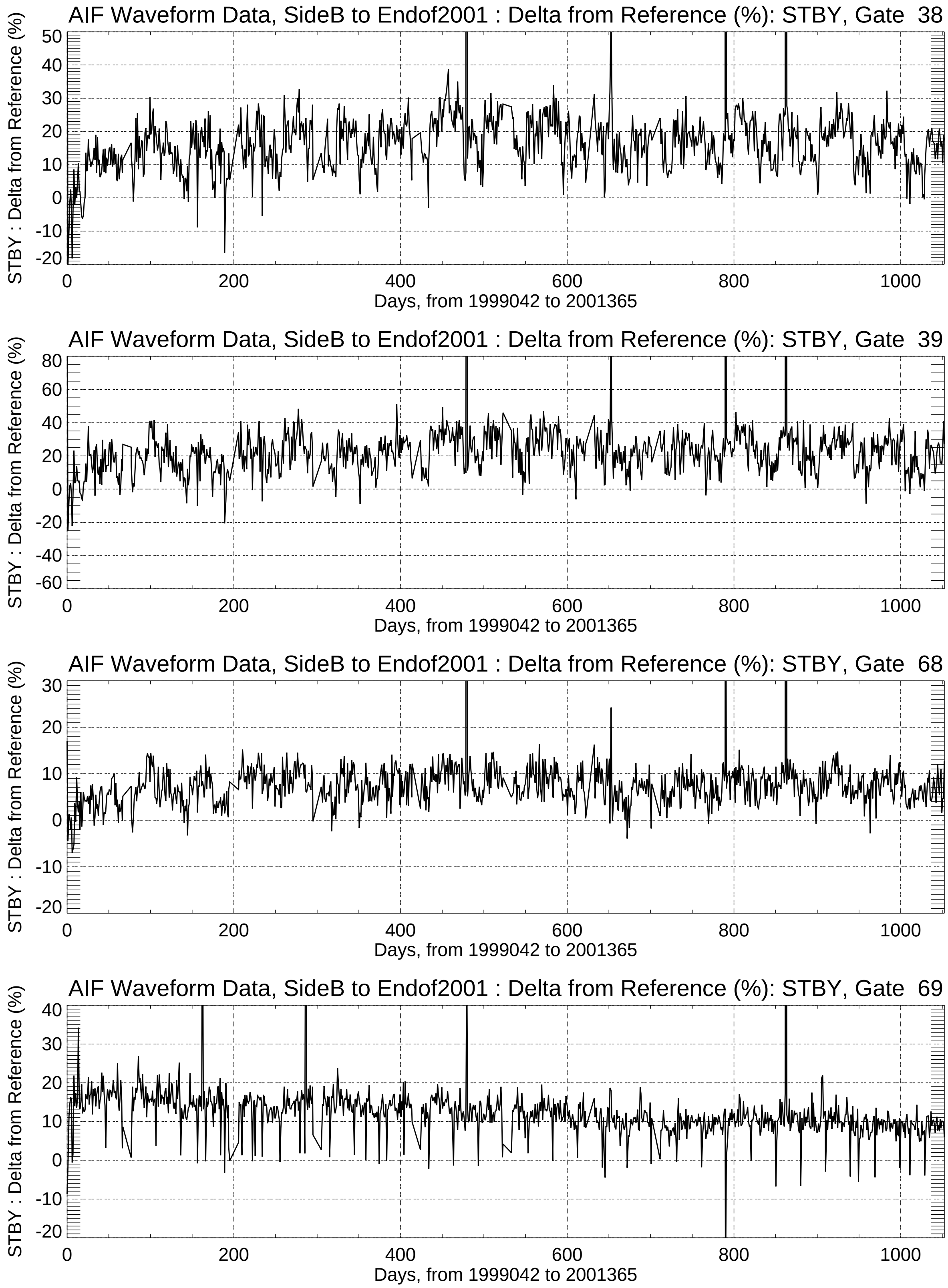


Figure 2-12 Ku-Band STANDBY Waveform Sample History

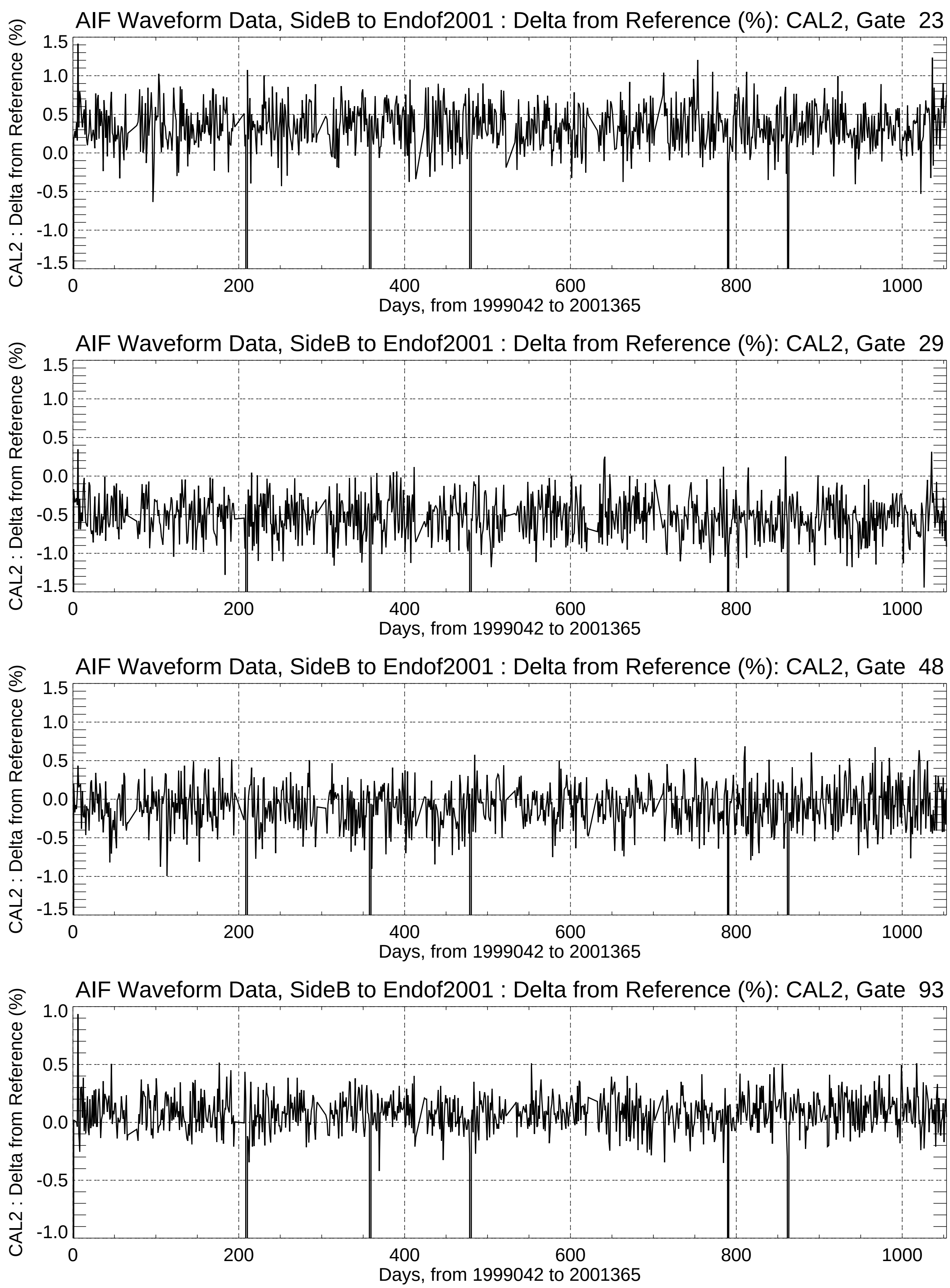


Figure 2-13 C-Band CAL-2 Waveform Sample History

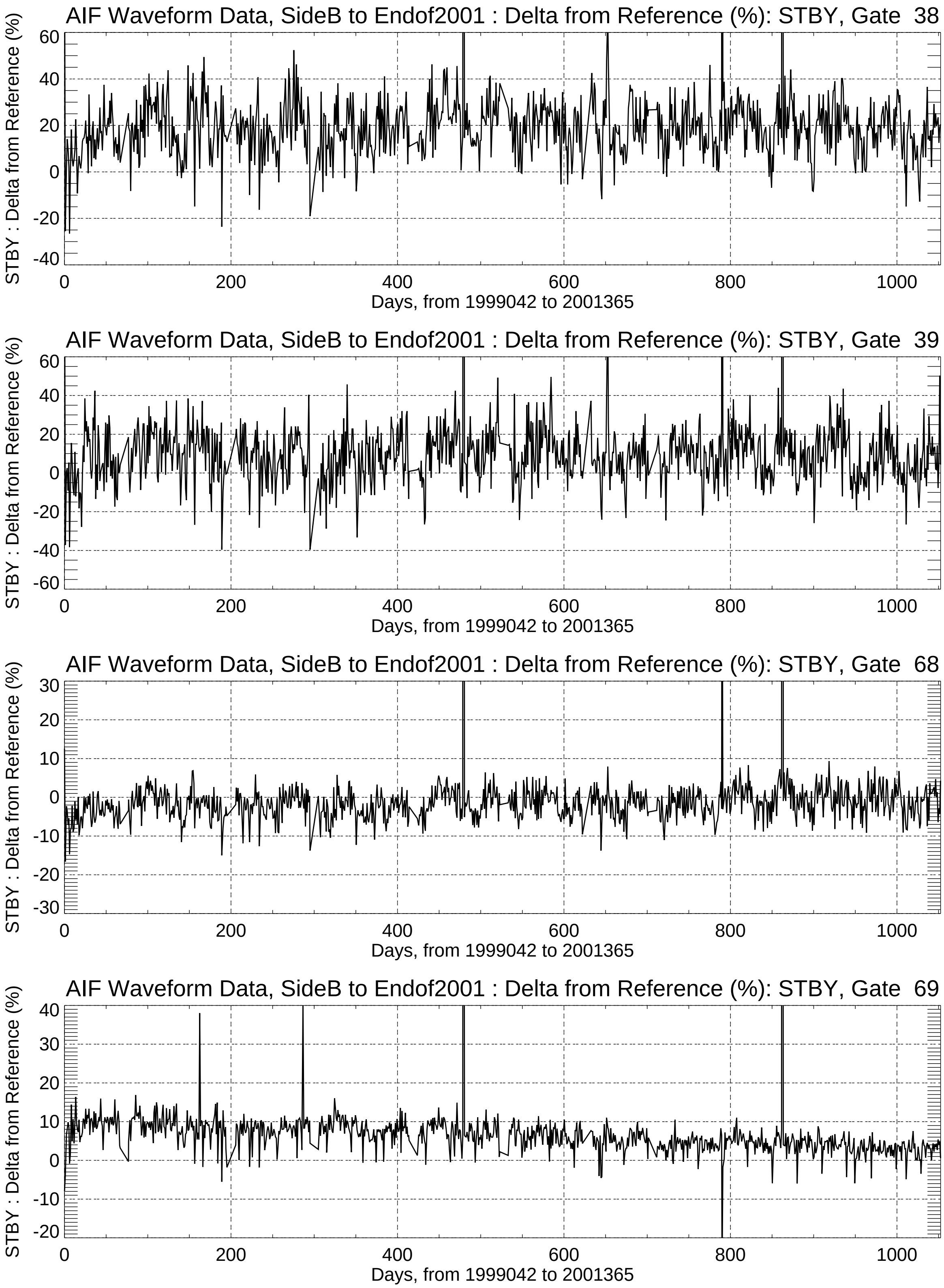


Figure 2-14 C-Band STANDBY Waveform Sample History

time periods, showing the average, the minimum, and the maximum values during each 24-hour period.

2.2.6.1 Temperatures

The temperatures of all 26 internal thermistors continued to be within the design temperature range and, except for the DCG Gate Array, are within the ranges experienced during the pre-launch Hot and Cold Balance Tests. The minimum / maximum values for each of the thermistors during TRACK mode remained within the bounds listed in Table 7.1 of the *TOPEX Mission Engineering Assessment Report*, February 1994, and they compose plots 2 through 27 in Figure 2-15 "Engineering Monitor Histories" on page 2-17.

As noted in last year’s assessment report, the DCG Gate Array temperature is about 30 degrees higher than that experienced during pre-launch testing. Further, the temperature has exhibited a slow rise since Side B turn-on of about one degree per year, as noted by Beth Fabinsky of JPL. A lifetime thermal analysis of a similar DCG Gate Array unit indicates there still should be no great concern.

Although not used during our routine monitoring, several of the altimeter-related baseplate temperature monitors serviced by Remote Interface Unit (RIU) 6B became uncalibrated on day 17 of 1995. The affected temperature monitors are listed in Section 2.2.6.1 of the 1996 Engineering Assessment Report. An abrupt change in the values occurred on that date, apparently due to a change in the current which is applied to the thermistor circuits.

2.2.6.2 Voltages, Powers and Currents

The altimeter's 17 monitors for voltages, powers and currents remained at consistent levels, with little deviations. Their Side B to end of 2000 histories are also shown in Figure 2-15 "Engineering Monitor Histories" on page 2-17.

The eight voltages [LVPS +12V, LVPS +28V, LVPS +15V, LVPS -15V, LVPS +5V(5%), LVPS +5V(1%), LVPS -5.2V and LVPS -6V], have changed very little since Side B turn-on.

The following changes since turn-on of Side B are noted:

- The TWA Helix current has decreased about 0.05 milliamperes.
- The C-Band Transmit Power has decreased approximately 1.2 watts since turn-on.
- There has been a gradual decrease in the CSSA Bus current level; the level has decreased 0.09 amp since turn-on.

2.2.7 Single Event Upsets

There have been a total of 158 Single Event Upsets (SEUs) from the initial turn-on of Side B to the end of 2001, an average of one SEU per 6.6 days. The vast majority of the SEUs occurred in the South Atlantic Anomaly, as shown in Figure 2-16 "Locations of SEU Occurrences" on page 2-28. The dots in Figure 2-16 denote the locations of normal SEU occurrences, while the diamonds indicate that the SEU was abnormal.

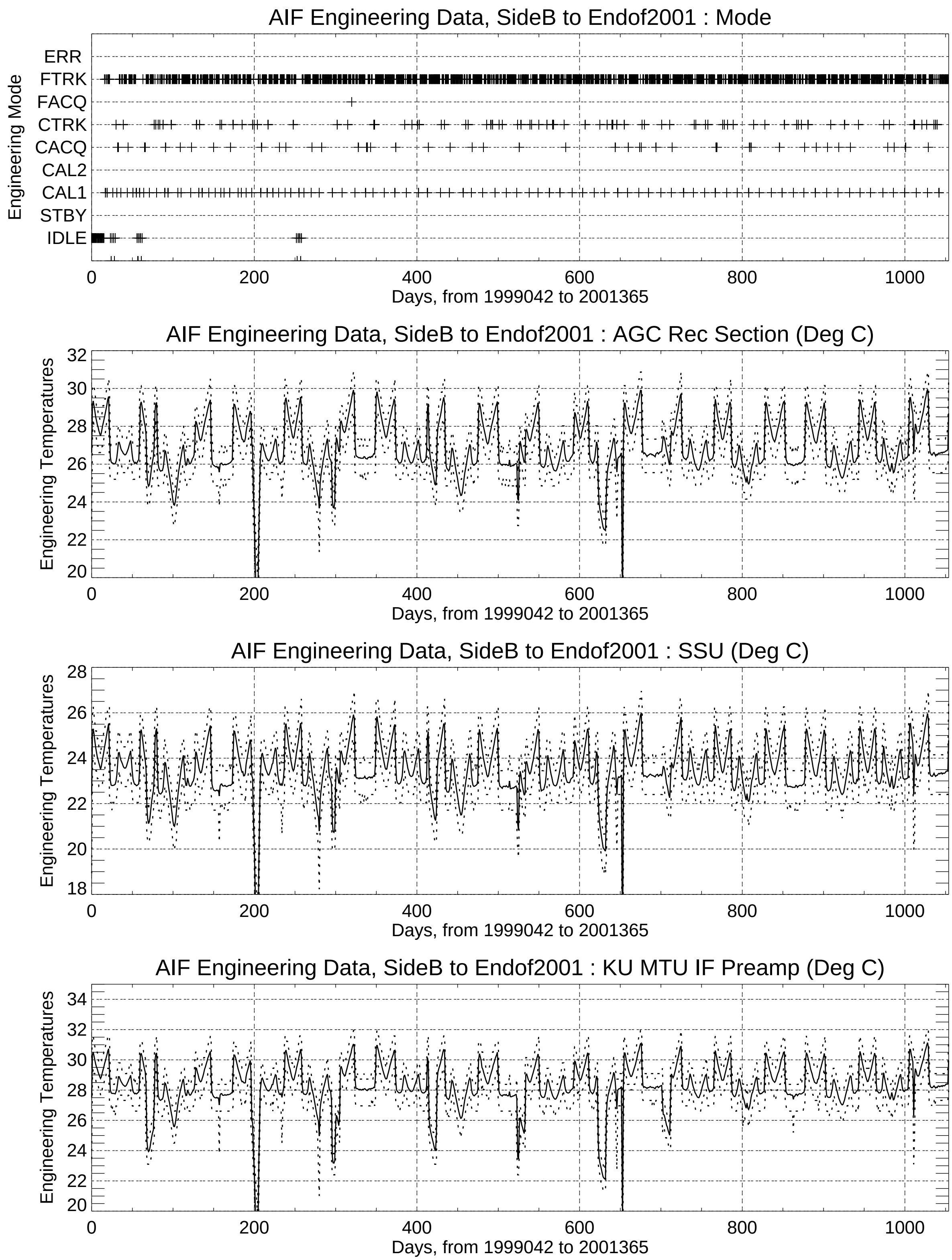


Figure 2-15 Engineering Monitor Histories

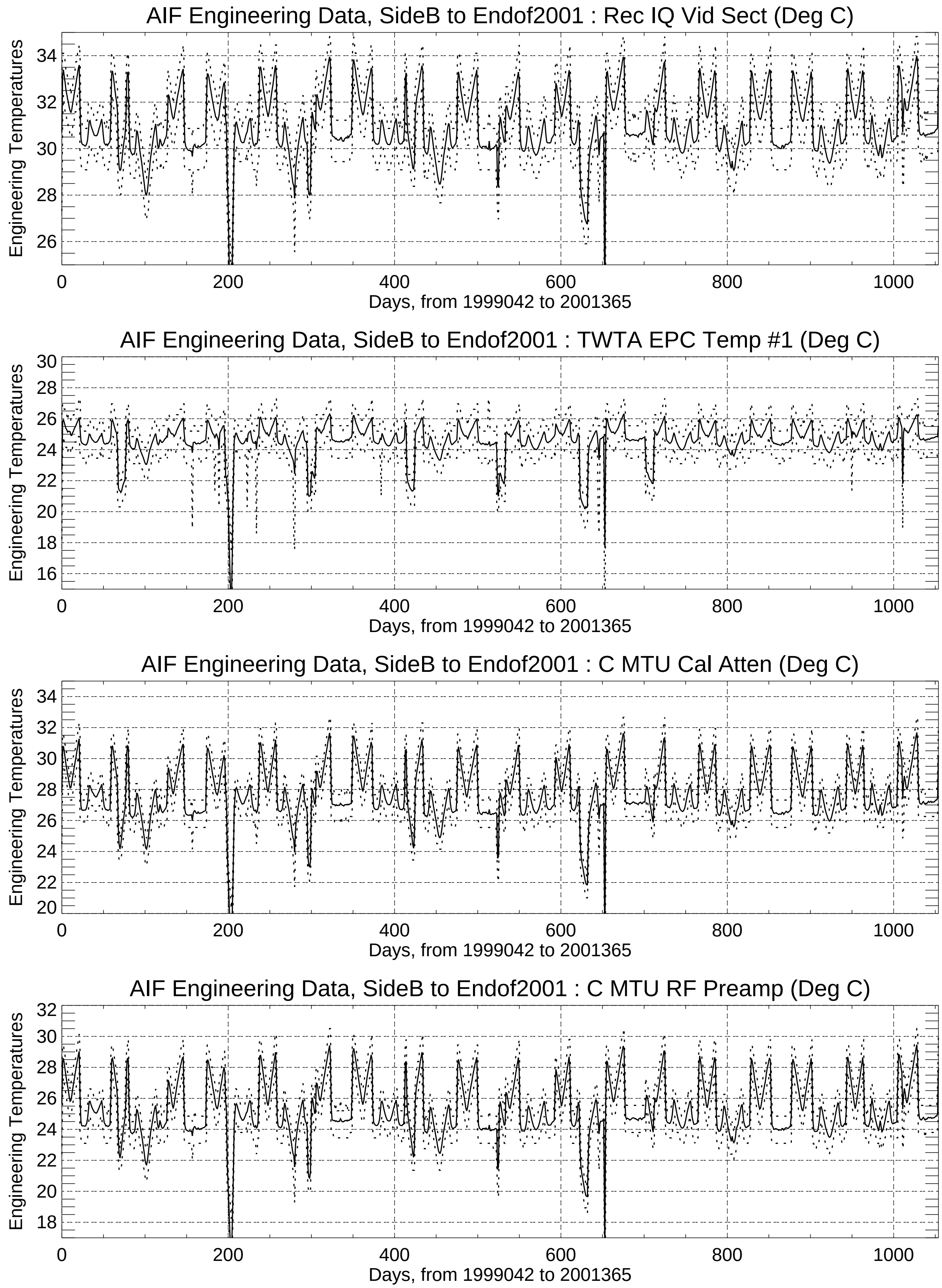


Figure 2-15 Engineering Monitor Histories (Continued)

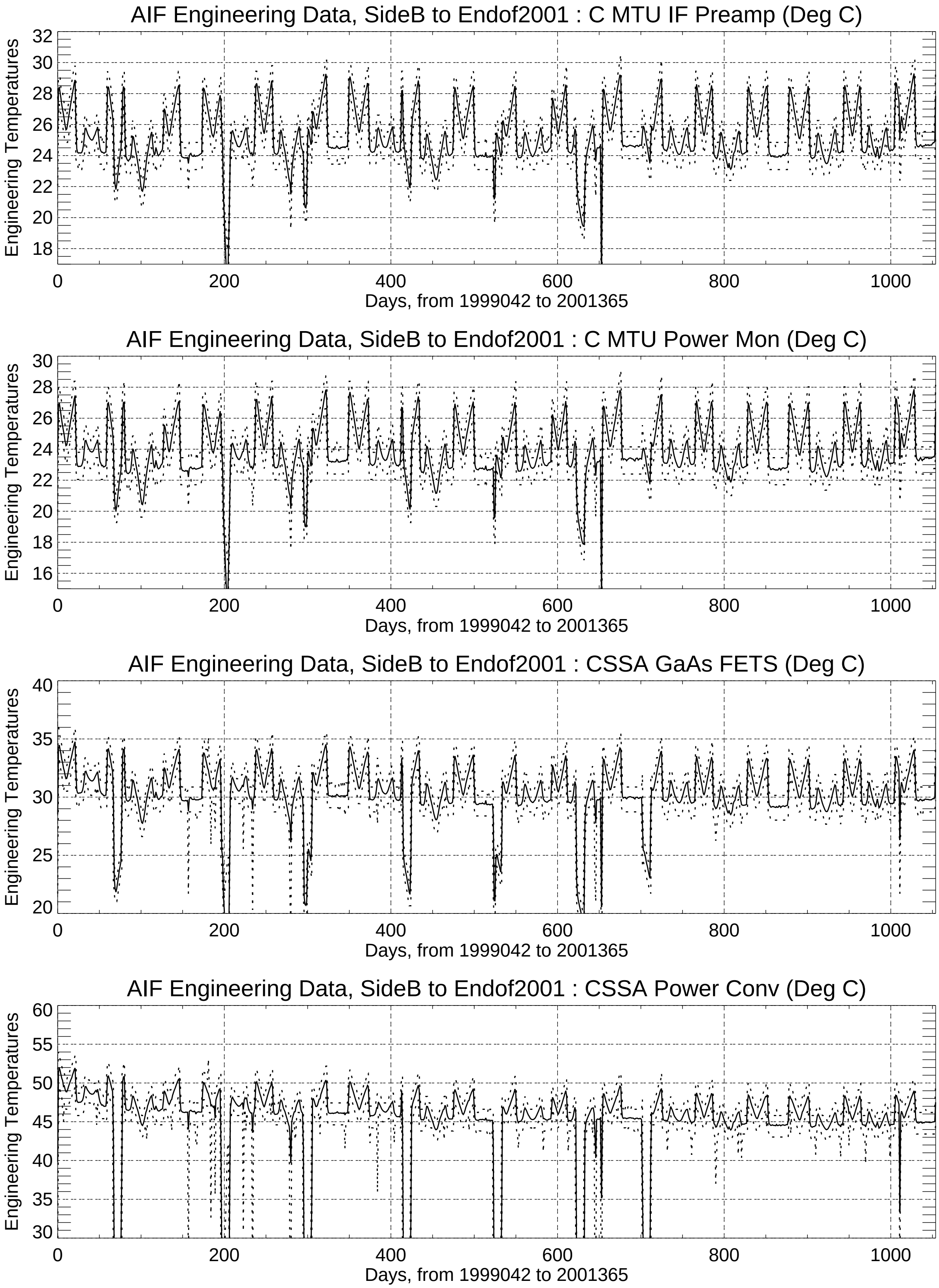


Figure 2-15 Engineering Monitor Histories (Continued)

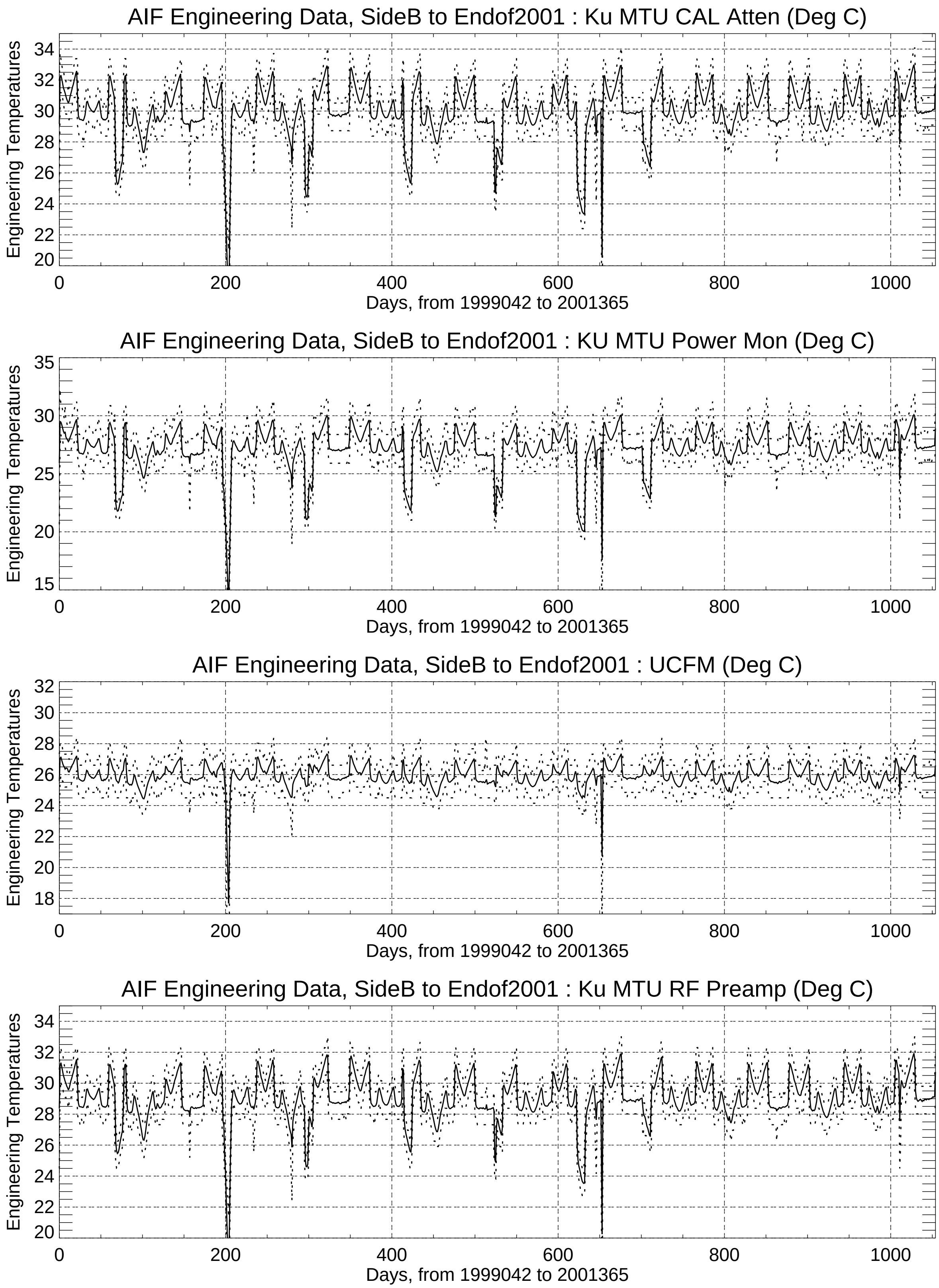
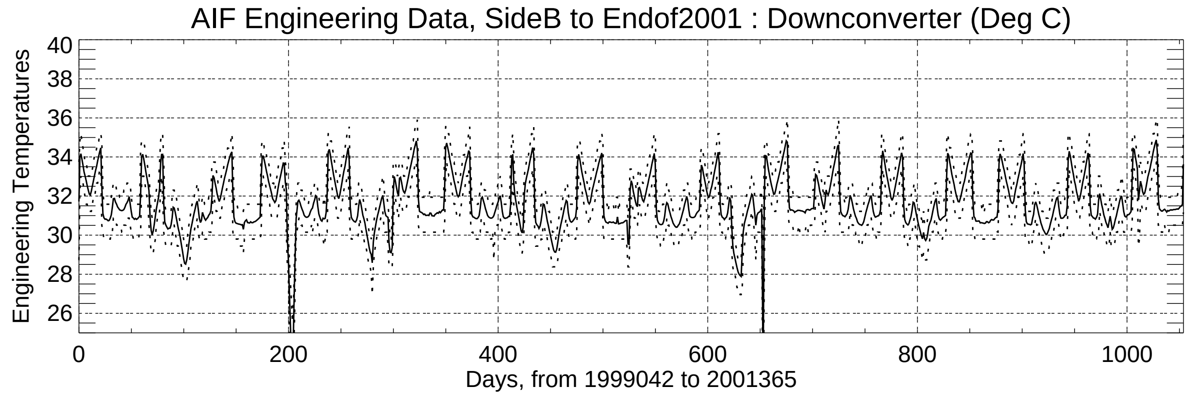
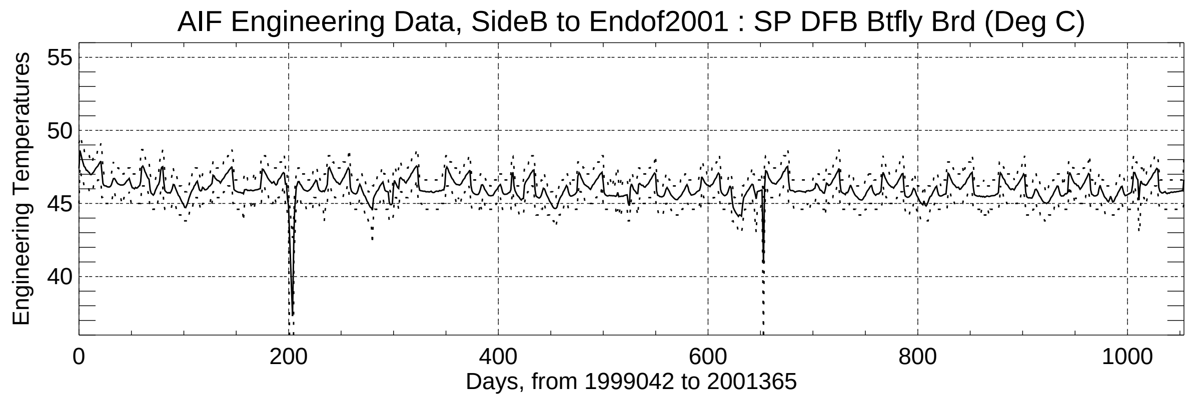
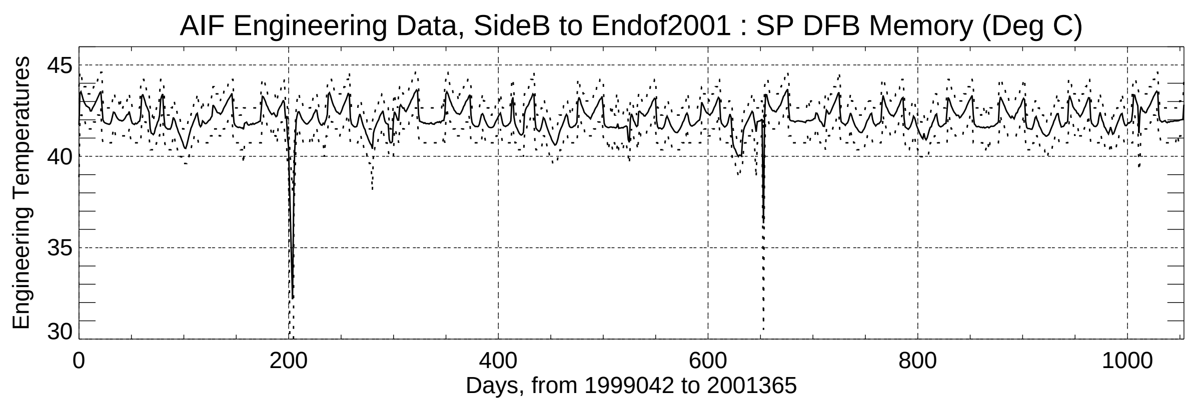


Figure 2-15 Engineering Monitor Histories (Continued)







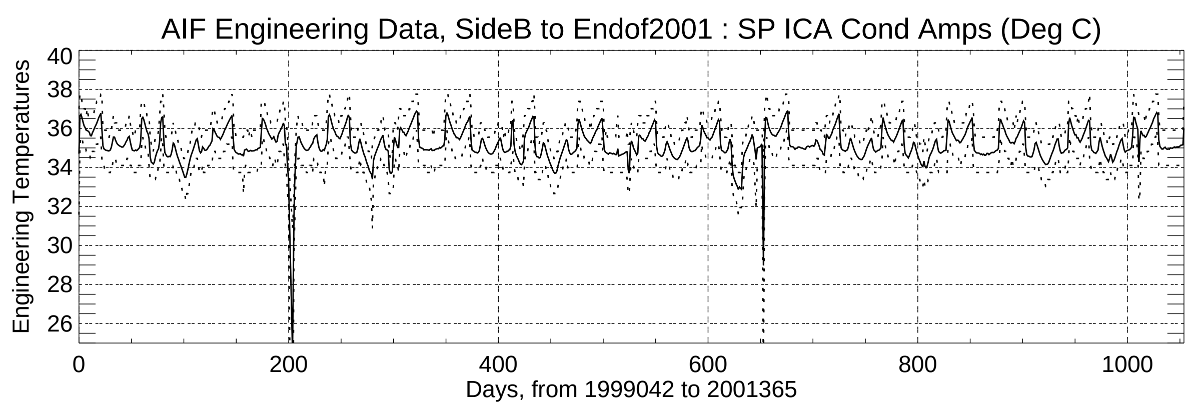


Figure 2-15 Engineering Monitor Histories (Continued)

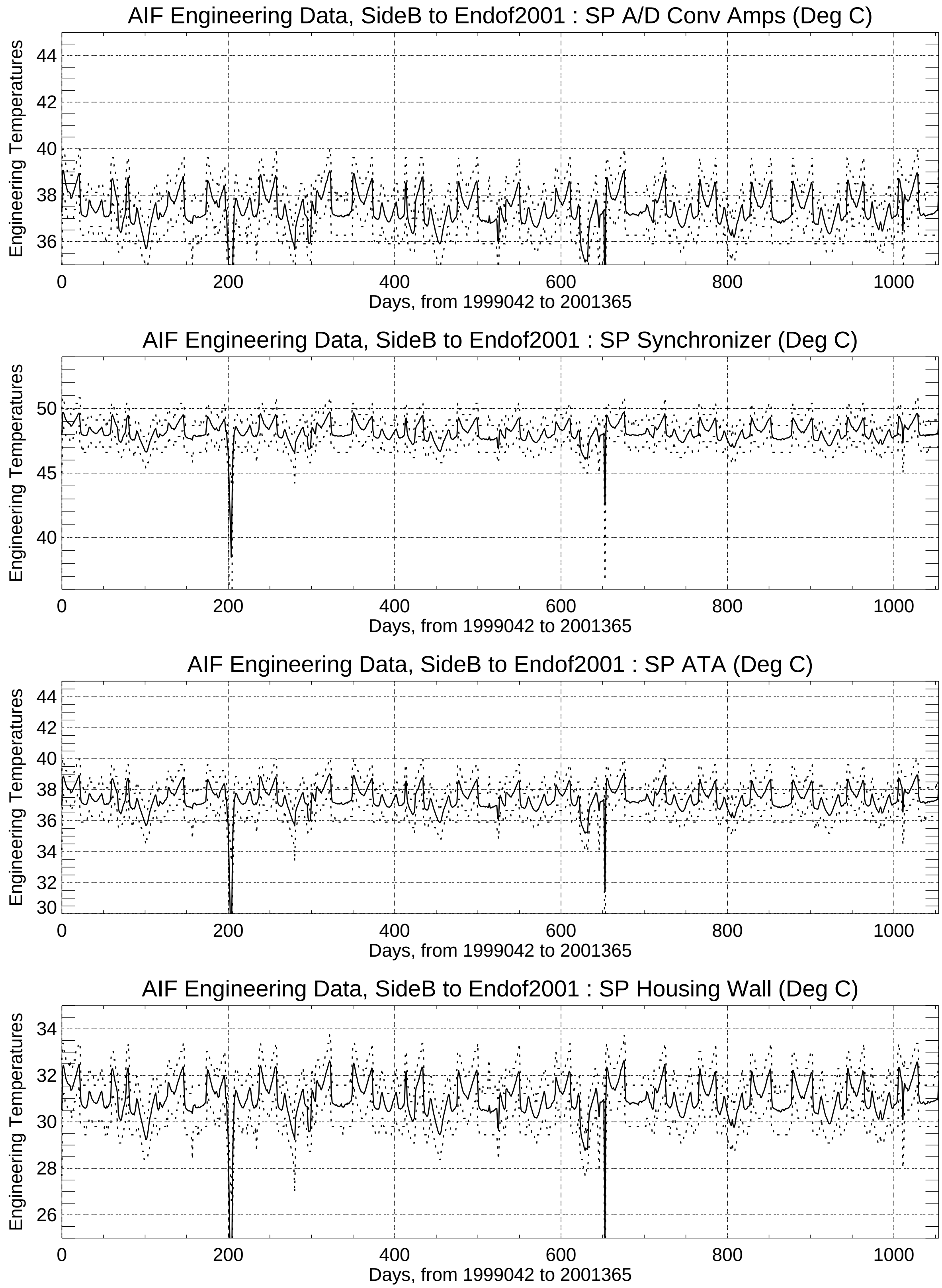
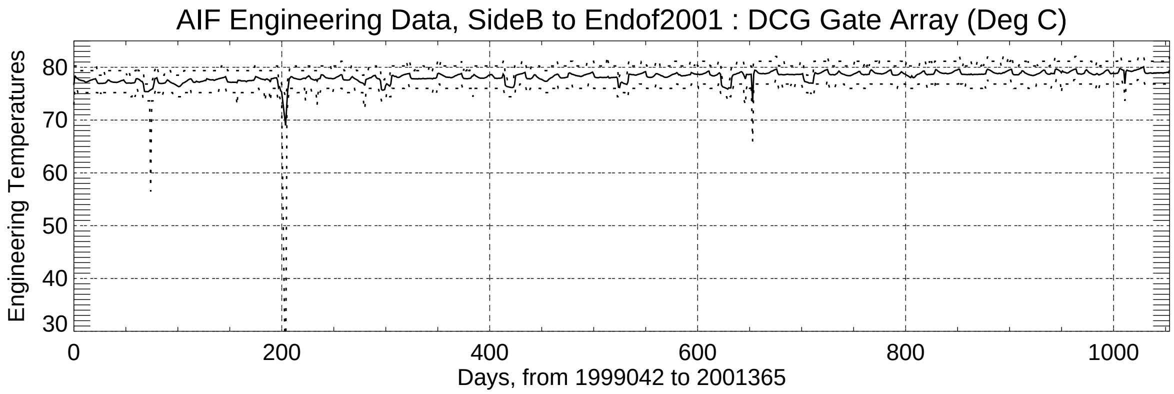
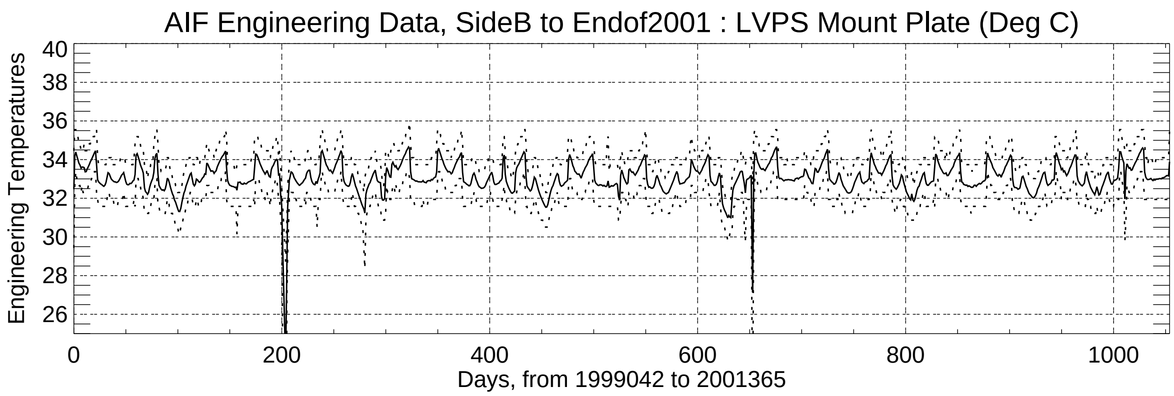
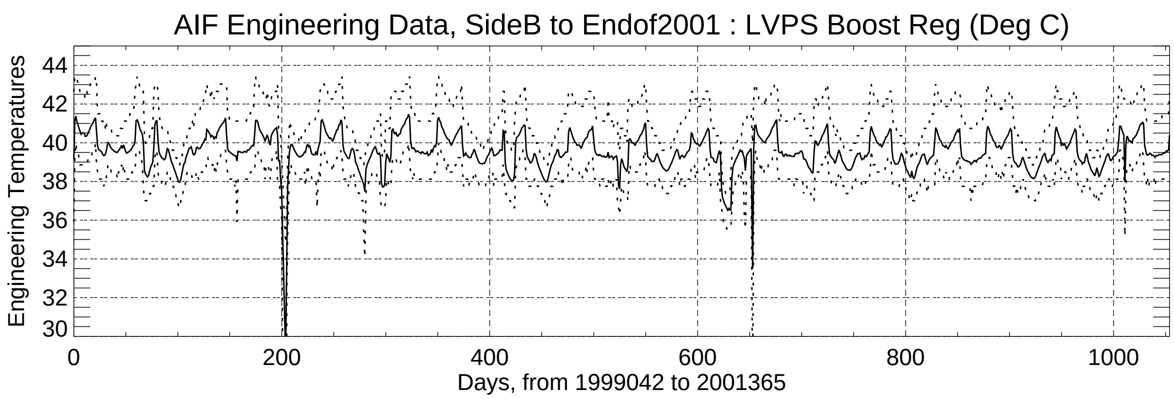


Figure 2-15 Engineering Monitor Histories (Continued)


AIF Engineering Data, SideB to Endof2001 : DCG Gate Array (Deg C)
Engineering Temperatures
80
70
60
50
40
30
0
200
400
600
800
1000
Days, from 1999042 to 2001365


AIF Engineering Data, SideB to Endof2001 : LVPS Mount Plate (Deg C)
Engineering Temperatures
40
38
36
34
32
30
28
26
0
200
400
600
800
1000
Days, from 1999042 to 2001365


AIF Engineering Data, SideB to Endof2001 : LVPS Boost Reg (Deg C)
Engineering Temperatures
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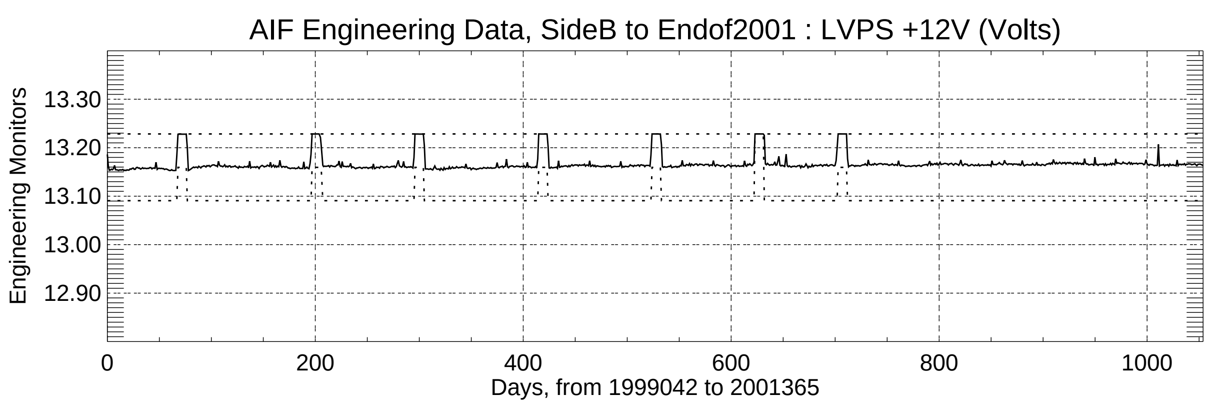
42
40
38
36
34
32
30
0
200
400
600
800
1000
Days, from 1999042 to 2001365


AIF Engineering Data, SideB to Endof2001 : LVPS +12V (Volts)
Engineering Monitors
13.30
13.20
13.10
13.00
12.90
0
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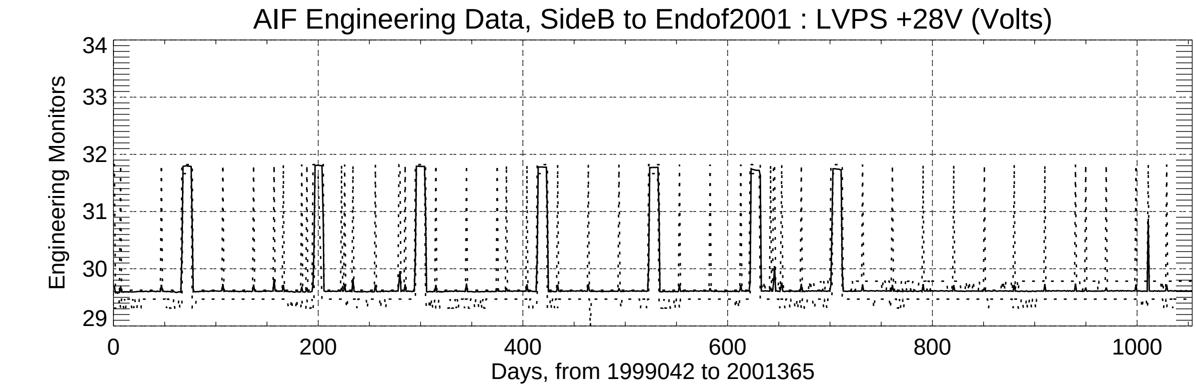
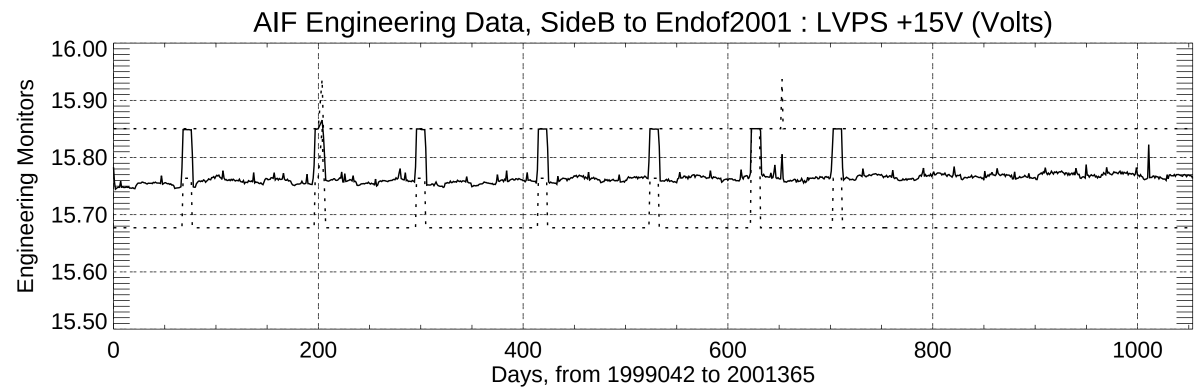
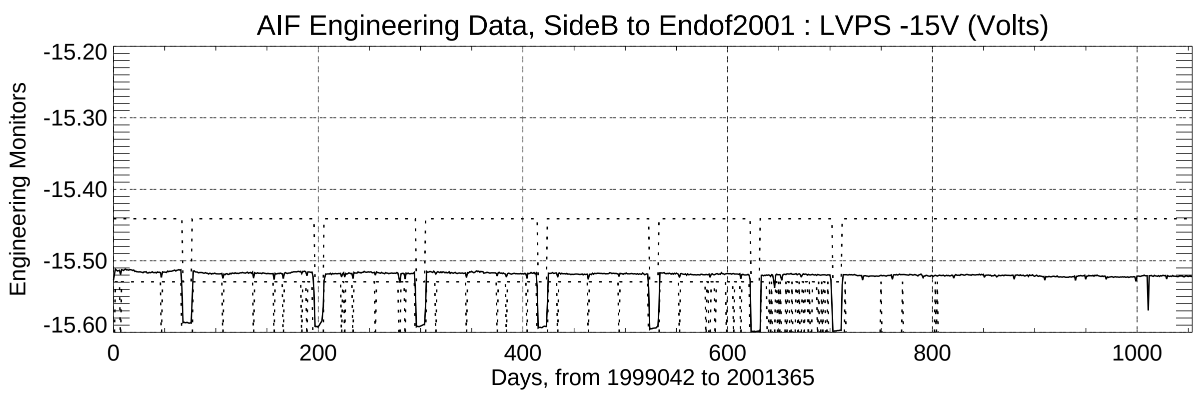
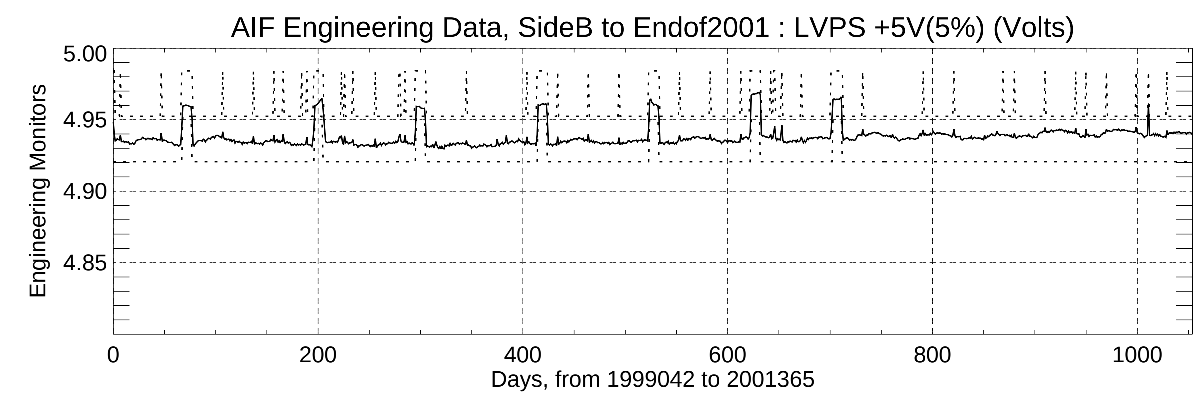
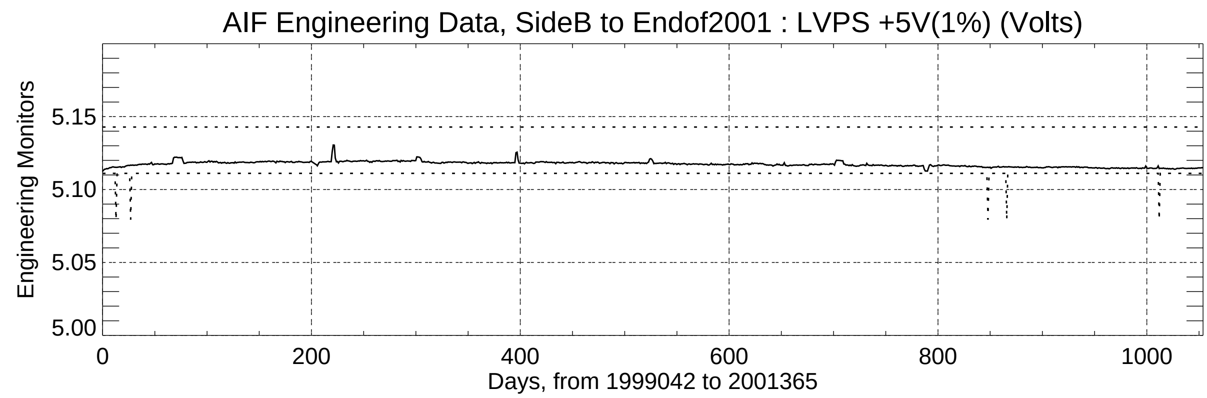
400
600
800
1000
Days, from 1999042 to 2001365

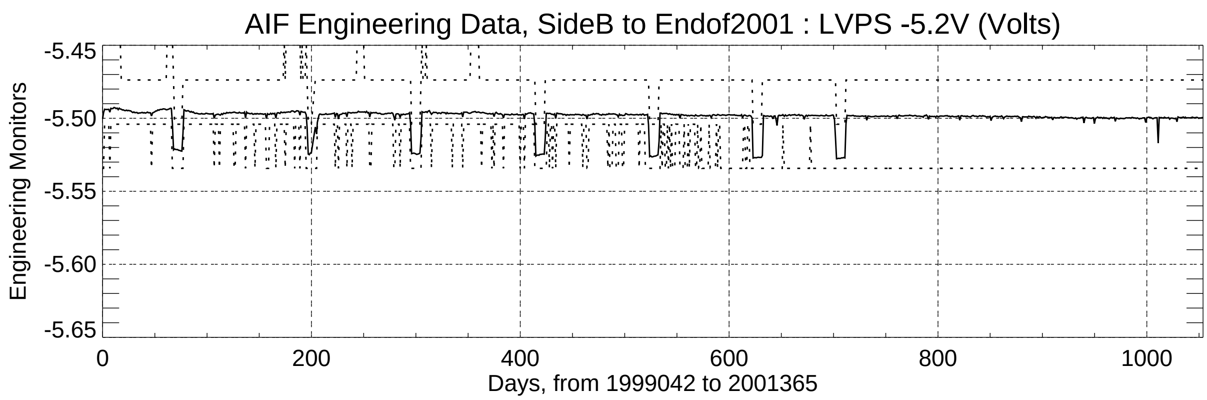

AIF Engineering Data, SideB to Endof2001 : LVPS +28V (Volts)
Engineering Monitors
34
33
32
31
30
29
0
200
400
600
800
1000
Days, from 1999042 to 2001365

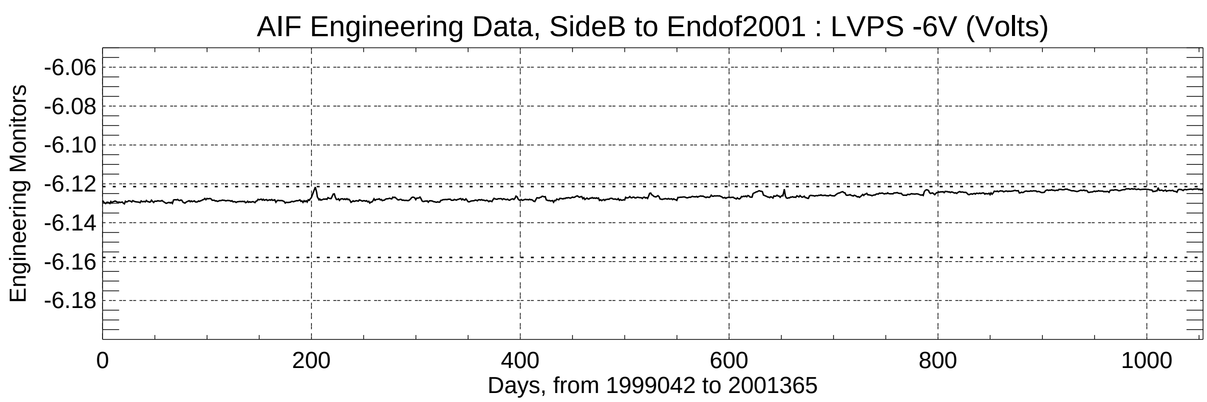

AIF Engineering Data, SideB to Endof2001 : LVPS +15V (Volts)
Engineering Monitors
16.00
15.90
15.80
15.70
15.60
15.50
0
200
400
600
800
1000
Days, from 1999042 to 2001365

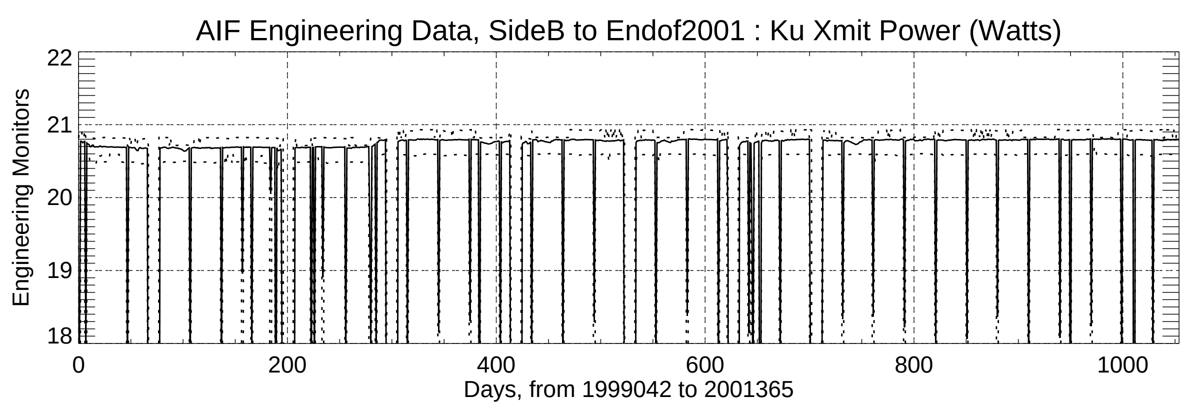

AIF Engineering Data, SideB to Endof2001 : LVPS -15V (Volts)
Engineering Monitors
-15.20
-15.30
-15.40
-15.50
-15.60
0
200
400
600
800
1000
Days, from 1999042 to 2001365

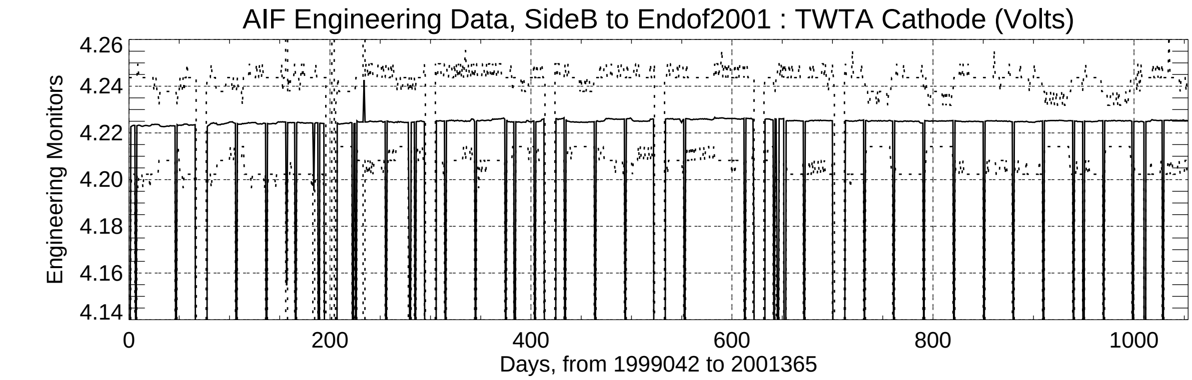

AIF Engineering Data, SideB to Endof2001 : LVPS +5V(5%) (Volts)
Engineering Monitors
5.00
4.95
4.90
4.85
0
200
400
600
800
1000
Days, from 1999042 to 2001365

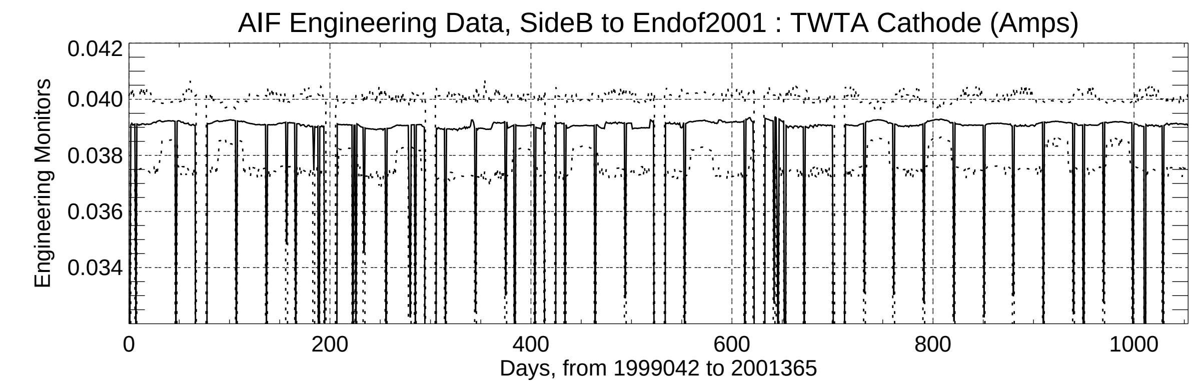

AIF Engineering Data, SideB to Endof2001 : LVPS +5V(1%) (Volts)
Engineering Monitors
5.15
5.10
5.05
5.00
0
200
400
600
800
1000
Days, from 1999042 to 2001365

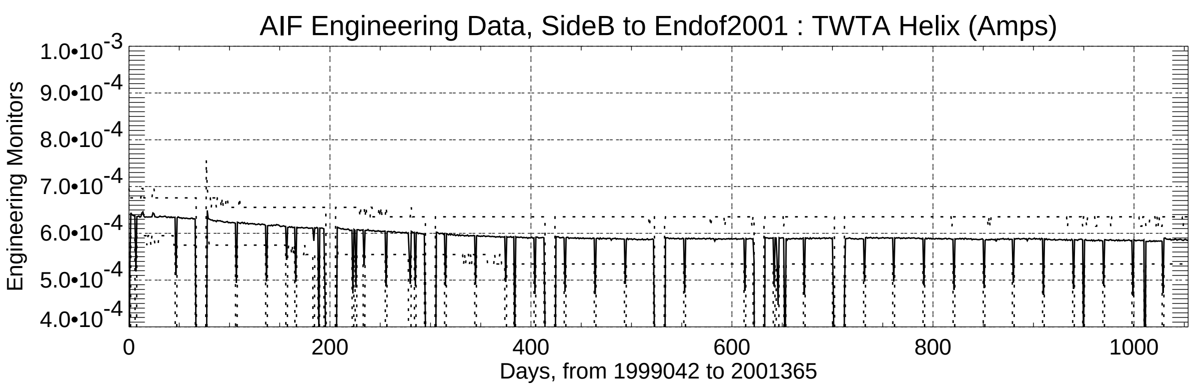

AIF Engineering Data, SideB to Endof2001 : LVPS -5.2V (Volts)
Engineering Monitors
-5.45
-5.50
-5.55
-5.60
-5.65
0
200
400
600
800
1000
Days, from 1999042 to 2001365

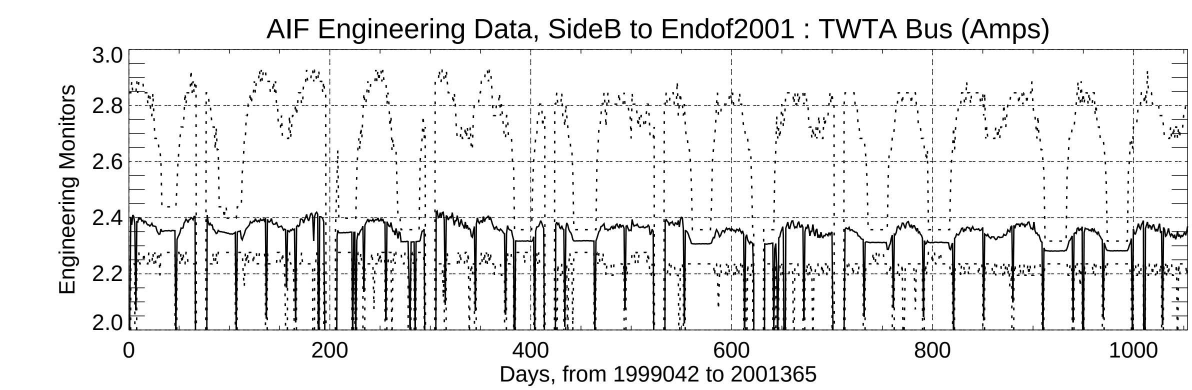

AIF Engineering Data, SideB to Endof2001 : LVPS -6V (Volts)
Engineering Monitors
-6.06
-6.08
-6.10
-6.12
-6.14
-6.16
-6.18
0
200
400
600
800
1000
Days, from 1999042 to 2001365

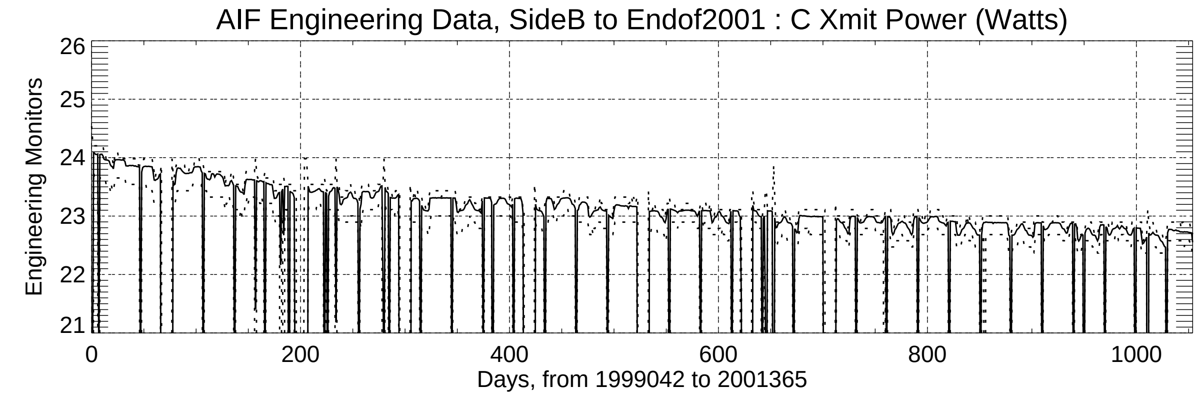

AIF Engineering Data, SideB to Endof2001 : Ku Xmit Power (Watts)
Engineering Monitors
22
21
20
19
18
0
200
400
600
800
1000
Days, from 1999042 to 2001365

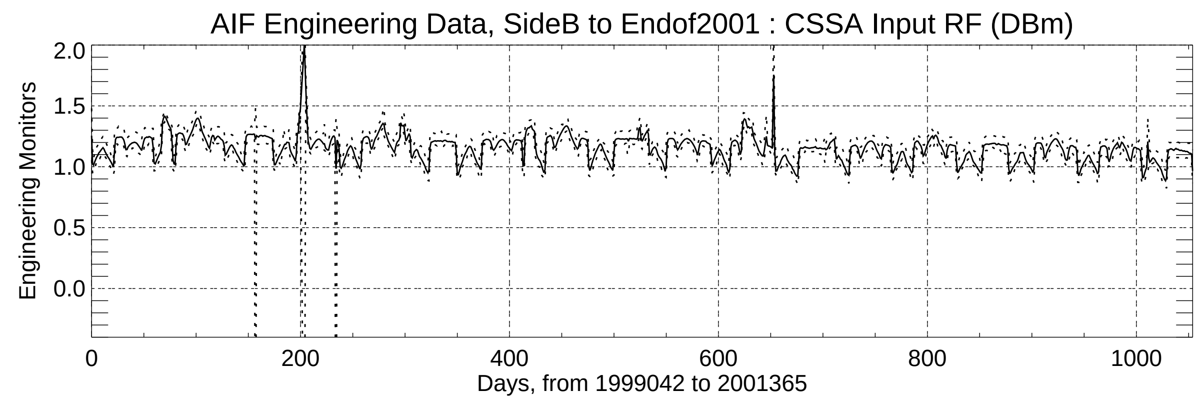

AIF Engineering Data, SideB to Endof2001 : TWTA Cathode (Volts)
Engineering Monitors
4.26
4.24
4.22
4.20
4.18
4.16
4.14
0
200
400
600
800
1000
Days, from 1999042 to 2001365

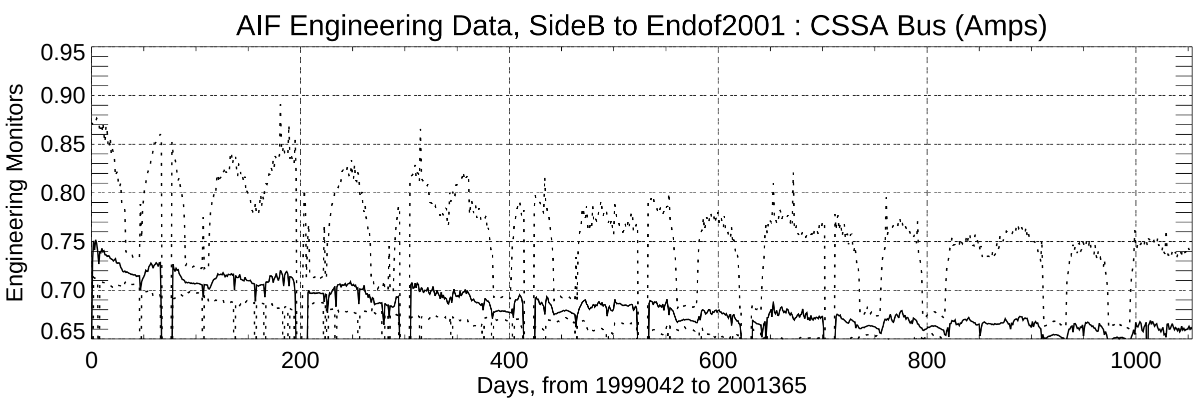

AIF Engineering Data, SideB to Endof2001 : TWTA Cathode (Amps)
Engineering Monitors
0.042
0.040
0.038
0.036
0.034
0
200
400
600
800
1000
Days, from 1999042 to 2001365

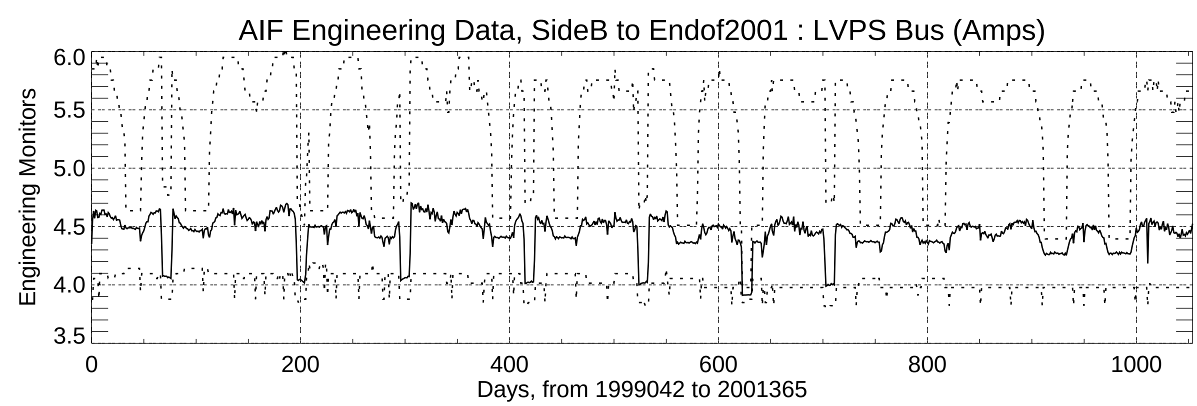

AIF Engineering Data, SideB to Endof2001 : TWTA Helix (Amps)
Engineering Monitors
1.0•10^-3
9.0•10^-4
8.0•10^-4
7.0•10^-4
6.0•10^-4
5.0•10^-4
4.0•10^-4
0
200
400
600
800
1000
Days, from 1999042 to 2001365


AIF Engineering Data, SideB to Endof2001 : TWTA Bus (Amps)
Engineering Monitors
3.0
2.8
2.6
2.4
2.2
2.0
0
200
400
600
800
1000
Days, from 1999042 to 2001365


AIF Engineering Data, SideB to Endof2001 : C Xmit Power (Watts)
Engineering Monitors
26
25
24
23
22
21
0
200
400
600
800
1000
Days, from 1999042 to 2001365


AIF Engineering Data, SideB to Endof2001 : CSSA Input RF (DBm)
Engineering Monitors
2.0
1.5
1.0
0.5
0.0
0
200
400
600
800
1000
Days, from 1999042 to 2001365


AIF Engineering Data, SideB to Endof2001 : CSSA Bus (Amps)
Engineering Monitors
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0
200
400
600
800
1000
Days, from 1999042 to 2001365


AIF Engineering Data, SideB to Endof2001 : LVPS Bus (Amps)
Engineering Monitors
6.0
5.5
5.0
4.5
4.0
3.5
0
200
400
600
800
1000
Days, from 1999042 to 2001365

The altimeter processor automatically recovered from 144 of the SEUs; the other 14 required manual (ground-based command) resets. The automatic resets, generally, resulted in the loss of only a few seconds of data.

As of January 1, 2002, there have been a total of 19 anomalous Side B resets (the 14 manual resets plus 5 additional abnormal automatic resets). Table 2-1 "Anomalous Single Event Upsets" on page 2-29 lists the dates of these 19 SEUs, along with the type of on-board reset and the duration of the effect on the data.

Regarding the 3 abnormal automatic resets since the last assessment report:

- Day 2001-070 - The waveforms were not updating and a range sweep was processed. The altimeter reset itself.
- Day 2001-166 - The waveforms were not updating and a range sweep was processed. The altimeter reset itself.
- Day 2001-306 - The waveforms were not updating and a range sweep was processed. The altimeter reset itself.

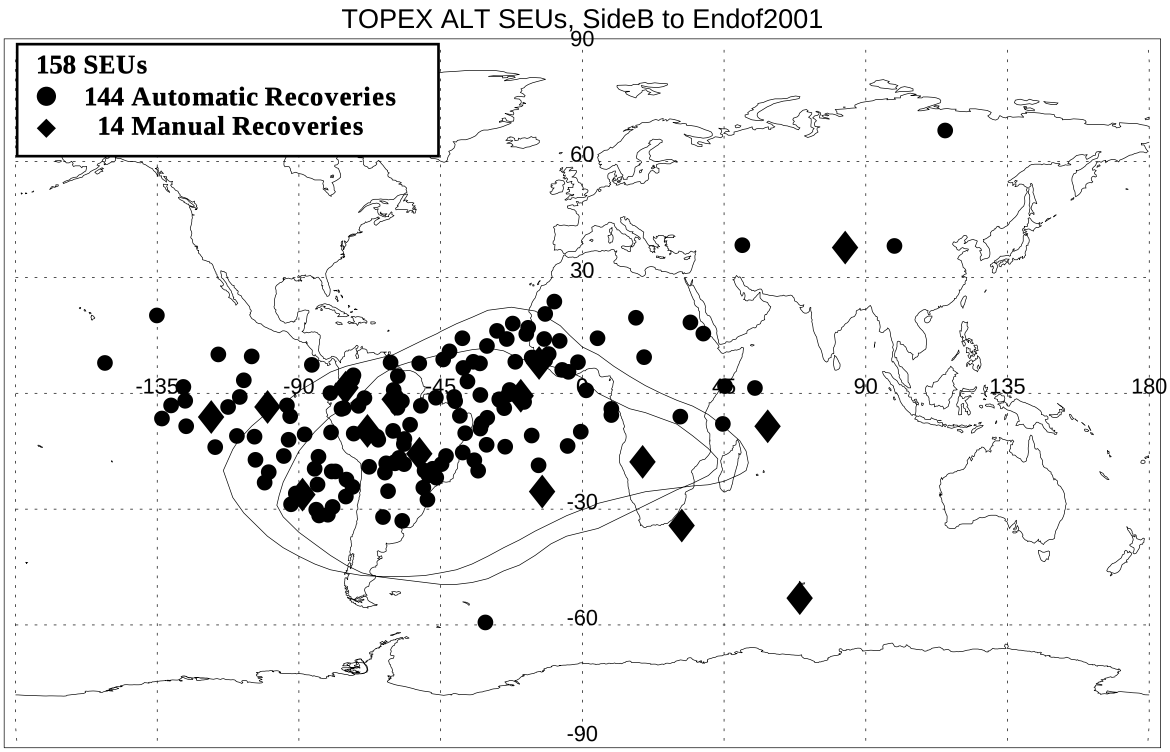


Figure 2-16 Locations of SEU Occurrences

Table 2-1 Anomalous Single Event Upsets

Year	Day	Duration (Hr)	Reset Type	Type SEU
Side B				
1999	071	0.7	Manual	DFB Interface Lockup
1999	198	5.6	Manual	C MTU Xmit
1999	223	1.6	Manual	Memory Corrupted
1999	246	13.0	Manual	Eng. Interface Lockup
1999	276	3.1	Manual	Ku MTU Xmit
1999	280	0.1	Automatic	No waveform update/Range Sweep
2000	056	0.1	Automatic	Eng. Spare Word Corrupted
2000	067	5.8	Manual	Sci. Telemetry Lockup
2000	157	1.9	Manual	DFB Interface Lockup
2000	227	1.4	Manual	Sci. Telemetry Lockup
2000	275	1.1	Manual	DFB Interface Lockup
2001	070	0.1	Automatic	No WF Update
2001	079	1.3	Manual	Sci Telemetry Lockup
2001	112	1.3	Manual	DFB Interface Lockup
2001	166	0.1	Automatic	No WF Update
2001	173	3.2	Manual	DFB Interface Lockup
2001	205	3.0	Manual	DFB Interface Lockup
2001	217	6.5	Manual	Sci. Telemetry Lockup
2001	306	0.1	Automatic	No WF Update
		Total = 50.0 Hrs		

2.3 Side B Key Events

The key events for TOPEX Altimeter Side B since its on-orbit turn-on are summarized in Table 2-2 "NASA Altimeter Side B - Key Events".

The listing of key events includes Cal Sweeps. In response to the altimeter's PTR change during Side A, a Cal Sweep software patch was developed, and was uploaded on day 250 of 1998. The purpose of this patch is to monitor the shape of the altimeter's CAL-1 waveform, looking for changes over time. Cal Sweeps are now regularly performed every 30 days, beginning with Side A on day 251 of 1998 and con-

Table 2-2 NASA Altimeter Side B - Key Events

Day	Event
1999/041	Commanded Side B to IDLE Mode and Uploaded Memory Patches
1999/042	Commanded Side B to STANDBY and then to TRACK Mode
1999/042	Side B Testing, including: Mode Checks, Cal-Sweep, and Waveform Leakage Tests
1999/043	Additional Testing, including: Cal-Sweep, Waveform Leakage Tests, and Gate-Shift Tests
1999/048	Gate Shift Tests (lost 3.1 hours of data)
1999/049	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/049-050	Off-Nadir Tests
1999/050	Began First Side B Operational Cycle [Cycle 237]
1999/071	Improper SEU Recovery (lost 0.7 hours of data)
1999/089	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/109	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/109	Changed to IDLE Mode for SSALT
1999/119	Returned to TRACK Mode
1999/119	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/149	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/179	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/198-199	C-Band Autonomously Switched to Side A Transmit (lost 5.6 hours of data)
1999/209	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/223	C-Band CAMPIN Autonomously Disabled (lost 1.6 hours of data). Some corruption of Non-Protected Memory
1999/226	Unsuccessful Restoration of Non-Protected Memory, due to Command Table Error (lost 0.6 hours of overland data)
1999/231	Successful Restoration of Non-Protected Memory (lost 1.1 hours of mostly overland data)
1999/236	Commanding for New Parameter File, to Increase AGC Minimum from 13 to 15 dB (lost 0.1 hours of overland data).
1999/237	Cal-Sweep Test (lost 0.4 hours of overland data)

Table 2-2 NASA Altimeter Side B - Key Events (Continued)

Day	Event
1999/238	Changed to IDLE Mode for SSALT
1999/243	Spacecraft Safehold, after a reset of central data processing unit. ALT was automatically turned OFF.
1999/243	Commanded ALT back to IDLE Mode. Total OFF time was 15.7 hours.
1999/244	Uploaded full memory dump command. ALT remains in IDLE.
1999/245	ALT turned OFF during Attitude Control Electronics switchover
1999/246	Commanded ALT back to IDLE Mode and Uploaded full memory dump command. ALT remains in IDLE. OFF time was 7.9 hours.
1999/248	Returned to TRACK Mode
1999/252	Digital Filter Bank Calibration (lost 0.3 hours of overland data)
1999/265	Sent Commands in Attempt to Improve Acquisition. Lost 1.1 hours of land and ocean data. Commanding was Unsuccessful.
1999/268	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/276	Ku-Band Autonomously Switched to Side A Transmit (lost 3.1 hours of data)
1999/298	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/327	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/337	Changed to IDLE Mode for SSALT
1999/347	Returned to TRACK Mode
1999/357	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/360	SEU resulted in corruption of the engineering Pass Count value. No apparent effect on ALT science data.
2000/012	Orbital Maneuver #13 (affected 1.2 hours of data)
2000/022	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/036	Digital Filter Bank Calibration (lost 0.3 hours of overland data)
2000/052	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/056-061	SEU at 056/141130 UTC resulted in corrupted engineering spare word. Memory reload on 061/070828 UTC corrected problem. ALT science data quality during the interim was apparently not affected.

Table 2-2 NASA Altimeter Side B - Key Events (Continued)

Day	Event
2000/061	Reloaded memory to rectify engineering memory corruption which began on day 056. Lost 0.9 hours of mostly overland data. This memory reload also restored the engineering Pass Count value which had been corrupted by an earlier SEU on 1999/360.
2000/067	Improper SEU recovery (lost 5.8 hours of data)
2000/081	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/091	Changed to IDLE Mode for SSALT
2000/101	Returned to TRACK Mode
2000/111	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/141	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/157	Improper SEU recovery (lost 1.9 hours of data)
2000/171	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/200	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/200	Changed to IDLE Mode for SSALT
2000/210	Returned to TRACK Mode
2000/227	Improper SEU recovery (lost 1.4 hours of data)
2000/230	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/260	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/275	Improper SEU recovery (lost 1.1 hours of data)
2000/290	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/299	Changed to IDLE Mode for SSALT
2000/309	Returned to TRACK Mode
2000/319	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/322	Changed to IDLE Mode for Leonid Meteor Shower (lost 2.0 hours of data)
2000/329	Spacecraft Safehold, ALT was automatically turned OFF due to bad ephemeris load.
2000/330	Commanded Alt back to Track. Total off time was 27.1 hours.
2000/349	Cal-Sweep Test (lost 0.4 hours of overland data)

Table 2-2 NASA Altimeter Side B - Key Events (Continued)

Day	Event
2000/352	Attitude Excursion to about 0.21 degrees for about 2000 seconds
2001/012	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/013	Changed to IDLE Mode for SSALT
2001/023	Returned to TRACK Mode
2001/036	The 'non-nominal' switch to Yaw Steering was caused by an OBC Euler-C Flag not being reset following the bad ephemeris load and Safehold of 11/23/00. (Flag was not reset due to an erroneous reinitialization command file). Lost 0.4 hours of data.
2001/043	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/070	Improper SEU recovery (lost 0.02 hours of data)
2001/072	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/079	Improper SEU recovery (lost 1.33 hours of data)
2001/101	Digital Filter-Bank Leakage Test and Transmit Test (lost 0.9 hours of data)
2001/102	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/112	Improper SEU recovery (lost 1.30 hours of data)
2001/132	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/162	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/166	Improper SEU recovery (lost 0.01 hours of data)
2001/173-174	Improper SEU recovery (lost 3.23 hours of data)
2001/191	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/205	Improper SEU recovery (lost 3.00 hours of data)
2001/217	Improper SEU recovery (lost 6.45 hours of data)
2001/221	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/251	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/258-261	SEU at 258/175123 UTC resulted in corrupted science spare word. Memory reload started on 261/035412 UTC corrected problem. ALT science data quality during the interim was apparently not affected.
2001/261	Reloaded memory to rectify science memory corruption which began on day 258. Lost 0.72 hours of mostly overland data.

Table 2-2 NASA Altimeter Side B - Key Events (Continued)

Day	Event
2001/281	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/310	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/322	Changed to IDLE Mode for Leonid Meteor Shower (lost 17.0 hours of data)
2001/340	Cal-Sweep Test (lost 0.4 hours of overland data)

tinuing through Side B operations. The results of the Side B Cal Sweeps are discussed in Section 3.3.

2.4 Side B Abnormalities

2.4.1 Land-to-Water Acquisition Times

Early in the Side-B Mission, there were occasional slow land-to-water acquisition times, first reported in Section 2.6 of the “TOPEX Radar Altimeter Engineering Assessment Report, Update: Side B Turn-On to January 1, 2000.” The anomaly affected only about 0.02% of the potentially available ocean data; it was last observed on day 243 of 1999.

Since that time, and throughout the year 2001, we have monitored the land-to-water acquisition times, and the anomaly has not recurred. We continue to monitor the acquisition times, and we continue to use the AGCMIN15 parameter file as our standard

2.4.2 Attitude Anomaly

A few short-duration attitude excursion anomalies, with maximum attitudes near 0.2 degree, were initially reported in the “TOPEX Radar Altimeter Engineering Assessment Report, Update: Side B Turn-On to January 1, 2001.”

There were two attitude excursions, similar to short-duration “Gyro spikes,” observed during the year 2001. The first spike, on day 2001-078, was the result of changes in the GYRO-A motor current. The second spike was on day 2001-330, in conjunction with a maneuver yaw unwind (OMM20).

The range noise, the AGC, and the SWH values appear reasonable throughout the attitude anomalies. There should be no consequence to the TOPEX data users, due to the TOPEX off-nadir corrections during ground processing being valid for attitudes out to 0.4 degree.

Section 3

Assessment of Instrument Performance (Cycles 236 through 342)

3.1 Range

The following range discussion is restricted to TOPEX Side B, from its start at cycle 236 on 1999 day 040 through cycle 342 which was the last cycle begun in year 2001 (cycle 342 started on 2001 day 360). Earlier years' assessment updates supplied cumulative results for Side A from launch to the end of the assessment update period, and the assessment update published in August 1999 provided the entire set of TOPEX Side A results from launch through Side A turnoff on 10 February 1999.

This report section discusses the Side B CAL-1 Step-5 Ku- and C-band delta ranges. The Calibration Mode was briefly reviewed in Section 2.1. The Ku- and C-band delta ranges have been processed to form a set of delta combined range values, where "combined" refers to the weighted sum of Ku- and C-band delta ranges which compensates for the ionospheric electron path delay. There are about twenty combined delta ranges for each TOPEX cycle, corresponding to two calibrations per day during the 10-day cycle. Early in Side A operation we developed a CAL-1 processing scheme to remove the effects of a 7.3 mm range quantization in the TOPEX internal calibration mode. The Side B is almost identical to Side A, the same calibration mode quantization is present in the CAL-1 delta range data, and we have used the same processing method to remove these quantization effects.

In previous years we had found that the Side A delta ranges had a temperature dependence. There are about two dozen different temperatures monitored within the TOPEX altimeter, and it is not possible to determine which of these is the most important to range bias. For our Side A analysis we had used the temperature of the upconverter / frequency multiplier unit (the UCFM), designating this temperature as Tu. The Ku-band delta range and the combined delta range varied somewhat with Tu, and we had found a simple quadratic correction of the combined delta range for Tu variation. Our previous years' assessment updates had tables of the range bias results with and without the correction for Tu, but we recommended that the TOPEX GDR data end user (who did not have easy access to the temperature data) should use the Side A combined delta range results that were NOT corrected for temperature Tu.

For Side B the behavior of delta range with temperature is somewhat different. We have found that the Ku-band range showed practically no temperature effect but that the C-band result did exhibit a temperature dependence, and that the C-band variation was more highly correlated with the receiver AGC temperature (designated Tagc here) than with Tu. Figure 3-1 "UCFM Temperature vs. Time" on page 3-2 shows the Side B Tu values through the end of cycle 342, and Figure 3-2 "AGC Receiver Temperature vs. Time" on page 3-2 shows the Tagc for the same period. Figure 3-3 "Side B Ku Cal 1 Step 5 Delta Height vs. Time" on page 3-3 and Figure 3-4 "Ku Cal 1 Step 5 Delta Height vs. Time, After Tagc Correction" on page 3-3 show the Side B Ku-band CAL-1

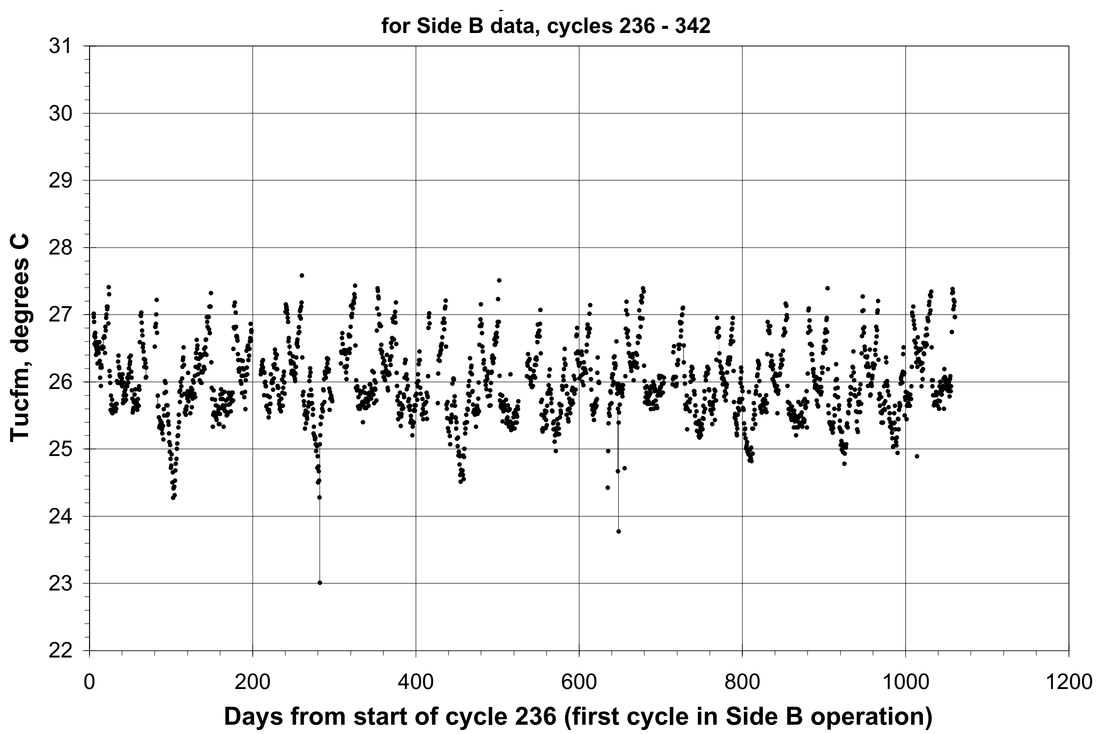


Figure 3-1 UCFM Temperature vs. Time

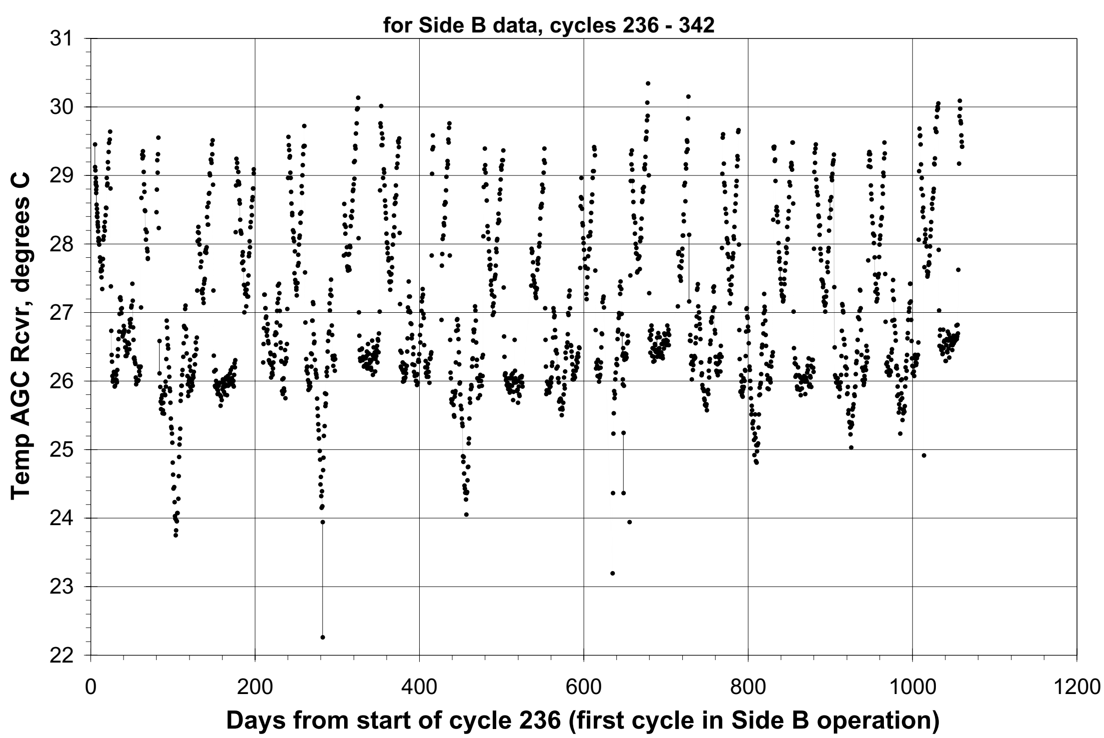


Figure 3-2 AGC Receiver Temperature vs. Time

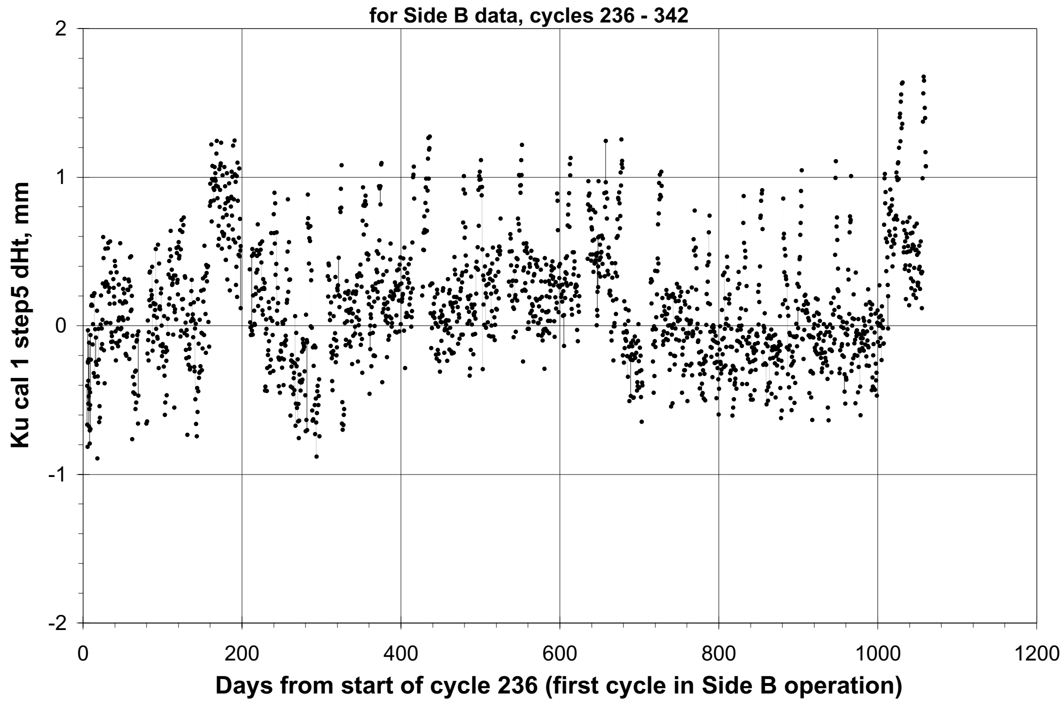


Figure 3-3 Side B Ku Cal 1 Step 5 Delta Height vs. Time

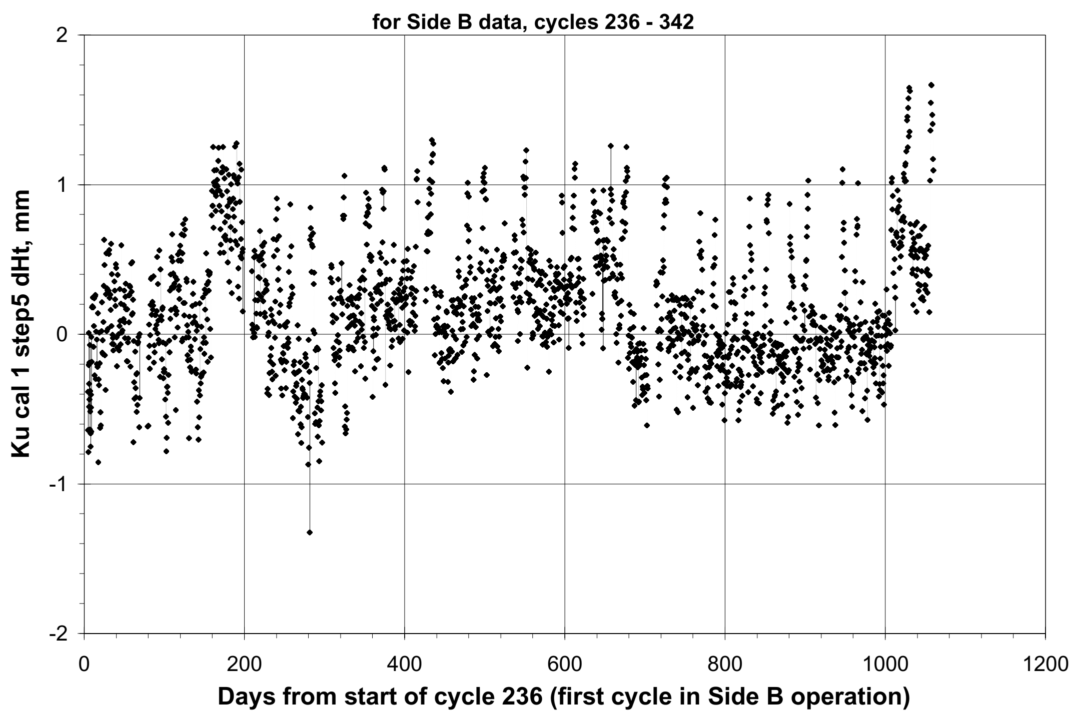


Figure 3-4 Ku Cal 1 Step 5 Delta Height vs. Time, After Tagc Correction

Step 5 delta range values for the same time span, before and after fitting a thermal correction which is quadratic in Tagc. It can be seen that the Tagc correction term has very little effect on the results. Figure 3-5 "C Cal 1 Step 5 Delta Height vs. Time" on page 3-4 and Figure 3-6 "C Cal 1 Step 5 Delta Height vs. Time, after Tagc Correction" on

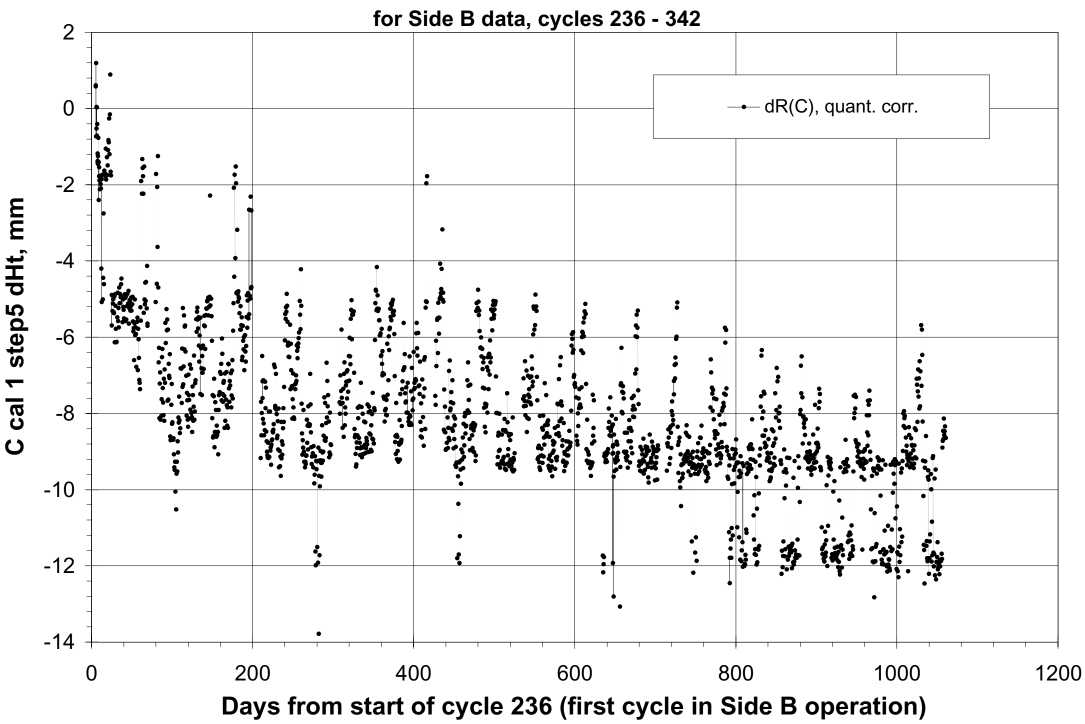


Figure 3-5 C Cal 1 Step 5 Delta Height vs. Time

page 3-5 show the corresponding Side B C-band delta range values, before and after Tagc correction, and it can be seen that the Tagc correction term does eliminate some of the variations of the individual data relative to the general trend. Figure 3-7 "Ku & C Combined Cal 1 Step 5 Delta Height vs. Time" on page 3-5 and Figure 3-8 "Combined Cal 1 Step 5 Delta Height vs. Time, After Tagc Correction" on page 3-6 compare the Side B combined delta range results with and without Tagc corrections and as we would expect from the Ku-band figures, the Tagc corrections have little discernible effect.

As for Side A, the general trend of delta ranges is slow enough that corrections can and should be made based on cycle averages of the CAL-based delta ranges. Figure 3-9 "Side B Combined (Ku & C) Delta Range vs. Cycle" on page 3-6 shows the set of cycle averages of the combined height delta ranges with NO temperature correction applied, and Figure 3-10 "Side B Combined (Ku & C) Delta Range vs. Cycle" on page 3-7 shows the cycle averages of combined delta ranges WITH the Tagc correction.There is no apparent benefit to using the Tagc correction for the combined delta range, and we strongly recommend using the Side B combined delta ranges with NO

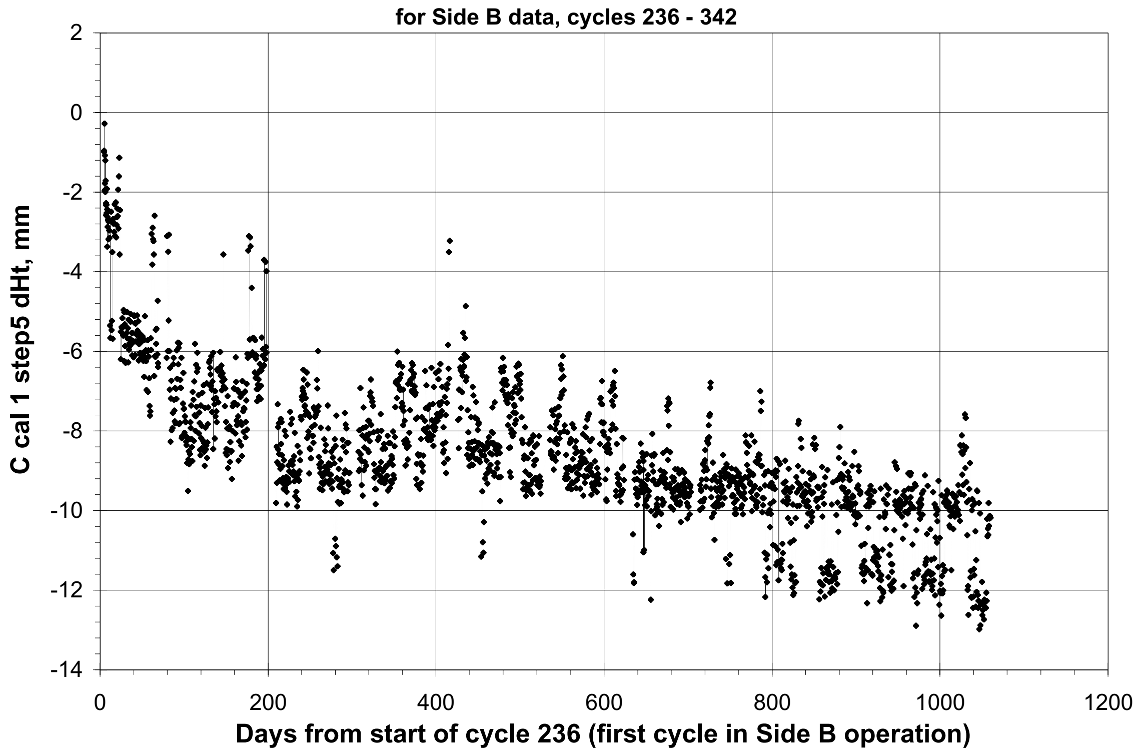


Figure 3-6 C Cal 1 Step 5 Delta Height vs. Time, after Tagc Correction

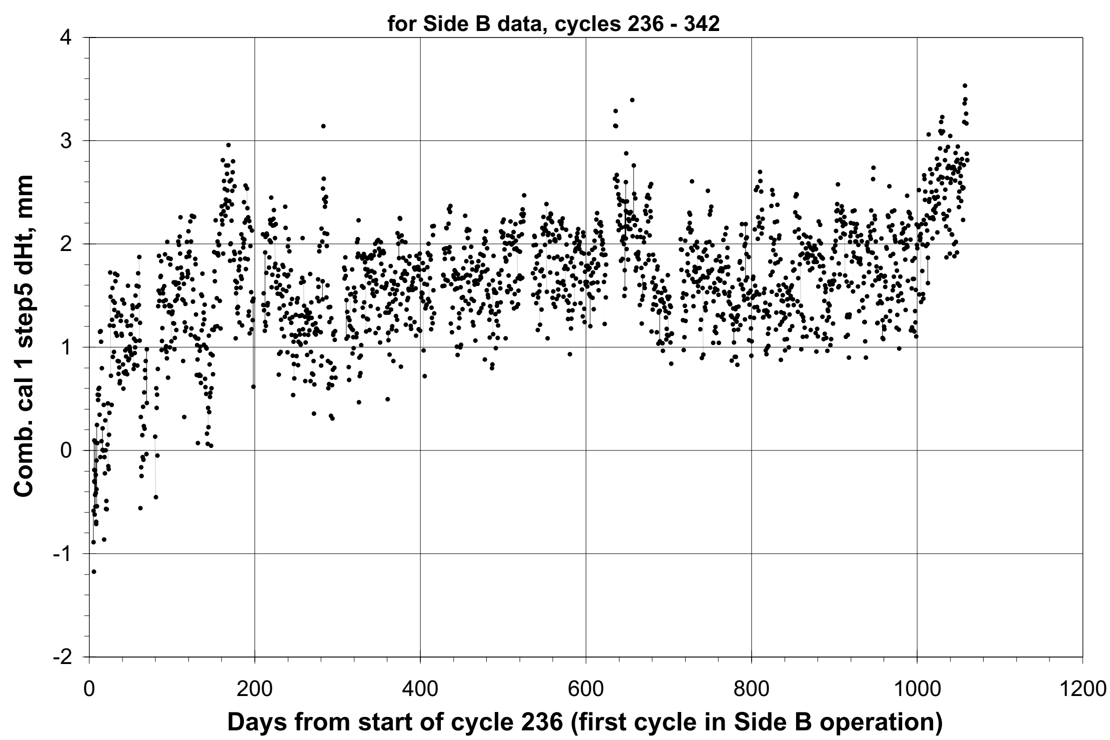


Figure 3-7 Ku & C Combined Cal 1 Step 5 Delta Height vs. Time

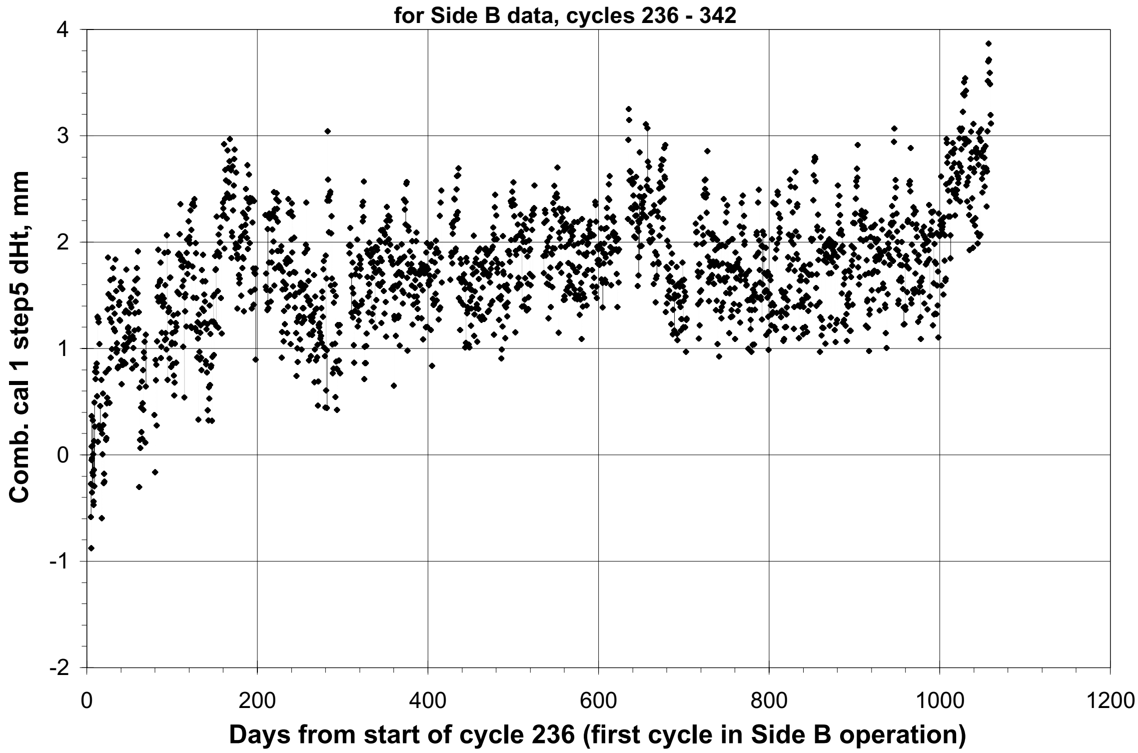


Figure 3-8 Combined Cal 1 Step 5 Delta Height vs. Time, After Tagc Correction

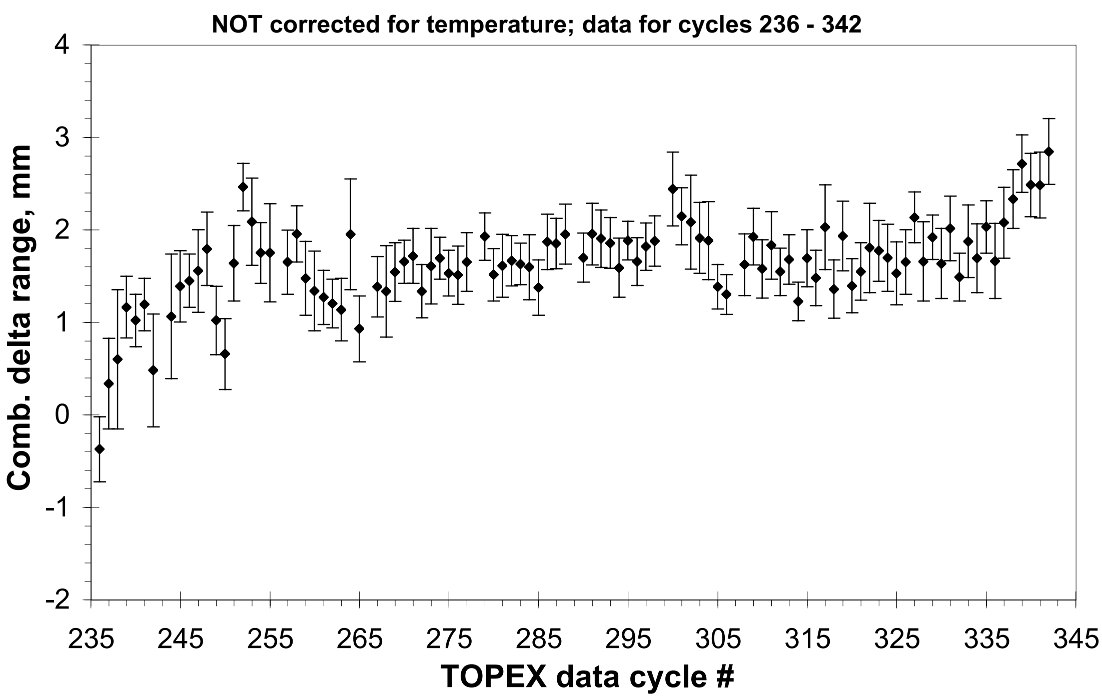


Figure 3-9 Side B Combined (Ku & C) Delta Range vs. Cycle

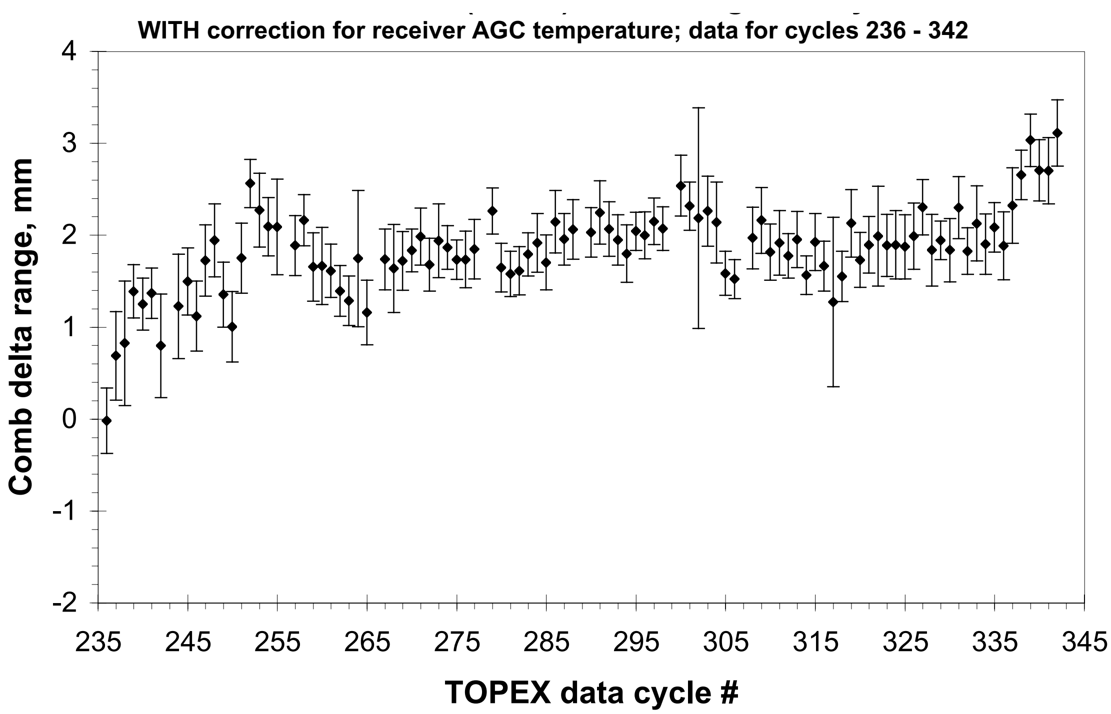


Figure 3-10 Side B Combined (Ku & C) Delta Range vs. Cycle

Tagc correction; these values are printed in Table 3-1 "TOPEX Range Bias Changes Based on Calibration Mode 1 Step 5".

Table 3-1 TOPEX Range Bias Changes Based on Calibration Mode 1 Step 5

Cycle #	Count	Avg dR (Comb), no temperature corr, mm	StDev dR (comb), no temperature corr, mm
236	21	-0.373	0.351
237	21	+0.336	0.490
238	20	+0.599	0.755
239	19	+1.163	0.333
240	20	+1.019	0.284
241	20	+1.191	0.284
242	21	+0.480	0.609
244	20	+1.062	0.673
245	19	+1.388	0.386
246	20	+1.448	0.288
247	20	+1.554	0.445
248	20	+1.793	0.398

Table 3-1 TOPEX Range Bias Changes Based on Calibration Mode 1 Step 5 (Continued)

Cycle #	Count	Avg dR (Comb), no temperature corr, mm	StDev dR (comb), no temperature corr, mm
249	20	+1.018	0.368
250	20	+0.657	0.383
251	19	+1.637	0.408
252	19	+2.460	0.256
253	20	+2.088	0.472
254	22	+1.749	0.328
255	21	+1.749	0.530
257	18	+1.649	0.346
258	20	+1.956	0.304
259	20	+1.473	0.400
260	20	+1.339	0.431
261	20	+1.269	0.292
262	20	+1.201	0.264
263	19	+1.135	0.338
264	21	+1.950	0.599
265	20	+0.929	0.356
267	20	+1.383	0.327
268	20	+1.335	0.494
269	19	+1.541	0.317
270	20	+1.654	0.234
271	20	+1.716	0.297
272	21	+1.334	0.288
273	20	+1.605	0.409
274	20	+1.690	0.226
275	18	+1.530	0.248
276	19	+1.509	0.316
277	21	+1.651	0.317
279	20	+1.927	0.257
280	19	+1.513	0.283

Table 3-1 TOPEX Range Bias Changes Based on Calibration Mode 1 Step 5 (Continued)

Cycle #	Count	Avg dR (Comb), no temperature corr, mm	StDev dR (comb), no temperature corr, mm
281	19	+1.609	0.339
282	20	+1.665	0.273
283	19	+1.630	0.223
284	19	+1.596	0.351
285	20	+1.375	0.299
286	20	+1.868	0.301
287	18	+1.851	0.273
288	20	+1.951	0.325
290	20	+1.697	0.265
291	20	+1.953	0.332
292	20	+1.903	0.312
293	18	+1.856	0.275
294	20	+1.589	0.318
295	19	+1.882	0.210
296	19	+1.654	0.258
297	20	+1.817	0.255
298	18	+1.878	0.271
300	20	+2.442	0.399
301	23	+2.147	0.309
302	19	+2.081	0.509
303	19	+1.910	0.384
304	19	+1.882	0.423
305	19	+1.384	0.242
306	20	+1.301	0.216
308	20	+1.623	0.333
309	20	+1.924	0.307
310	19	+1.578	0.316
311	20	+1.830	0.365
312	20	+1.544	0.257

Table 3-1 TOPEX Range Bias Changes Based on Calibration Mode 1 Step 5 (Continued)

Cycle #	Count	Avg dR (Comb), no temperature corr, mm	StDev dR (comb), no temperature corr, mm
313	19	+1.678	0.267
314	20	+1.224	0.208
315	21	+1.691	0.310
316	19	+1.478	0.301
317	20	+2.027	0.459
318	20	+1.358	0.315
319	20	+1.932	0.377
320	20	+1.393	0.292
321	19	+1.548	0.311
322	19	+1.803	0.483
323	19	+1.773	0.328
324	20	+1.697	0.362
325	20	+1.530	0.340
326	20	+1.651	0.348
327	19	+2.132	0.275
328	19	+1.657	0.428
329	20	+1.918	0.238
330	18	+1.633	0.379
331	20	+2.013	0.349
332	20	+1.488	0.256
333	20	+1.874	0.392
334	19	+1.692	0.372
335	20	+2.031	0.283
336	20	+1.662	0.406
337	20	+2.076	0.383
338	20	+2.330	0.318
339	20	+2.714	0.312
340	19	+2.484	0.342
341	20	+2.482	0.355

Table 3-1 TOPEX Range Bias Changes Based on Calibration Mode 1 Step 5 (Continued)

Cycle #	Count	Avg dR (Comb), no temperature corr, mm	StDev dR (comb), no temperature corr, mm
342	20	+2.844	0.356

These values are also available at our TOPEX web site
http://topex.wff.nasa.gov/docs/RangeStabUpdate.html,

and that web site is updated every month or so. The web site table also has the delta ranges which are temperature corrected for Tu using the correction developed for Side A. It was a mistake to calculate the Side A correction for the Side B data on the web site, and the Tu correction should be ignored. The simple rule for Side B is to use the delta range that has NO temperature correction.

To correct the GDR range data for the range calibration drift, one would use

Corrected Range = GDR range - dR_av_N,

where dR_av_N is the cycle-average delta combined range value of Table 3-1(as plotted in Figure 3-9). Note that the delta ranges are all given relative to a constant but arbitrary range offset, so this correction will provide only a relative range drift correction. The corresponding expression for correcting the GDR sea surface height (SSH) is

Corrected SSH= GDR SSH + dR_av_N.

3.2 AGC/Sigma0

The ocean surface's radar backscattering cross section, one of the quantities estimated by the TOPEX radar altimeter, is designated by σ^o which for typographical convenience is often referred to as sigma0 or sigma-naught; in this report section we will use sigma0. Most altimeters will eventually drift in their power estimation and hence in their sigma0 estimation. To correct for such drift, the TOPEX ground data processing includes a lookup table of sigma0 corrections. We will refer to that table as the "Cal Table" (the relevant TOPEX ground data processing system filename is SPA_ALT_CALPAR.TXT). In this section we describe the sigma0 trends from start of Side B (cycle 236) through cycle 345. Our sigma0 trend analyses use the sigma0 before the Cal Table corrections have been applied, and we refer to this as sigma0_uncorr.

3.2.1 Processing of Calibration Mode Results and Global Sigma0 Averages

As part of our continuing TOPEX support, we do daily quick-look processing of all TOPEX altimeter data for performance monitoring, providing performance summaries for the engineering and science data. The daily processing results are used to update a launch-to-date engineering database. Also, data are processed from the twice-daily execution of the altimeter's internal calibration mode (with submodes CAL-1 and CAL-2) and these results are used to update a WFF launch-to-date calibration database. We also process the intermediate geophysical data record (IGDR) data as they become available for network access, normally several days after the altimeter acquires the data. The IGDR data are processed for altimeter performance, and 1-minute summary records are produced and are added to a WFF launch-to-date GDR database. When the final GDR data become available, they replace the IGDR data already in our database. There is no difference, however, between sigma0 data on the IGDR and the GDR, because no further sigma0 corrections are made in going from the IGDR to the GDR.

We have been very concerned about possible contamination of the data by what we have called “sigma0 blooms”, regions of over-ocean altimeter data characterized by unusually high apparent sigma0 values accompanied by unusual altimeter waveform shapes. Generally the Ku-and the C-band sigma0 show the same behavior in a bloom region. Such blooms in the TOPEX data can persist for several tens of seconds, and the waveforms in a bloom region generally have too rapid a plateau decay. Many of these waveforms are too sharply peaked (“specular”), indicating a breakdown in the general incoherent scattering theory used to characterize the rough surface scattering. The sigma0 blooms exist in perhaps 5% of all TOPEX over-ocean data (there is additional sigma0 bloom information at http://topex.wff.nasa.gov/blooms/blooms.html). For input to our GDR database 1-minute averages, we require all the available altimeter flags to show normal tracking and the land/water flag to show deep water. When the data are extracted from this database for the sigma0 calibration, all records are rejected having Ku-band sigma0 estimates of 16 dB or greater or having waveform-estimated attitude angles of 0.12 degrees or greater. These editing criteria delete most of the sigma0 blooms.

Because our analysis is based on sigma0_uncorr, we need to know what Cal Table values have been already applied to the GDR (or IGDR) data in order to “undo” these corrections.

3.2.2 History of Cal Table Values Used in GDR Production

There were eighteen Cal Table adjustments during the TOPEX Side A operation. For Side B operation there have been six additional Cal Table adjustments after the initial Side B Cal Table was set. There exists no single summary elsewhere of exactly when each of the Cal Table changes was implemented in the TOPEX Side B ground processing so we will provide that summary here. The Side A Cal Table history has been described year by year in earlier Engineering Assessment Updates, and the entire Side A history is summarized at http://topex.wff.nasa.gov/docs/Sigma0Cal_A_All.pdf.

Each time the Cal Table contents are changed in the TOPEX ground data processing at JPL, there are at least three items created within JPL’s Mission Operations System (MOS):

- the MOS Change Request Form (the MCR) bears an origination date, describes the change to be made and the desired operational date for the change, and also has the date when the MCR was approved (by a change control board at JPL);
- the Parameter File is the text file to be actually used in the data processing and contains the Cal Table values for each cycle; and

- the File Release Form contains the Parameter File creation date, the release approval date, and the date at which file execution is to begin.

The MCR Form is typically accompanied by other supporting information from WFF describing why the change is being requested.

In Table 3-2 we have summarized information from copies of the sigma0-related MCRs and File Release Forms relevant to the re-released GDRs and the MGDR-Bs. Columns 1 to 3 of Table 3-2 are transcribed from the MCR Forms, and columns 4 and 5 from the File Release Forms. Column 6 of Table 3-2 contains a brief indication of what change the MCR made and why, and column 7 indicates which of the TOPEX Side B GDRs were governed by each MCR.

Table 3-2 Sigma0 Related MCRs and File Release Form Information

From MCR Form			From File Release Form		Additional Information	
(1) MCR #	(2) MCR Origination Date	(3) Comments on MCR Form	(4) File Creation Date	(5) Release Approval Date	(6) Comments on MCR actions and reasons	(7) Cycles Distributed, This MCR
690	99/05/26 1999-146	After indicated parameter & constant changes, produce IGDrs and GDRs from all Alt-B data to date	1999/05/25 1999-145	1999/05/28	After initial Cal/Val activity, set constant Ku and C biases with values chosen to make smooth connection to Side A results	236 - 247
692	99/06/16 1999-167	see attachment request memo from P. Callahan	1999/06/17 1999-168	1999/06/17	C-band has a trend estimated from first 12 cycles (1st C-band change is at cycle 242), Ku-band has zero trend.	248 - 258
701	2000/01/10 2000-010	Begin use for cycle 259.	2000/01/13 2000-013	2000/01/13	Put in linear trend for Ku, and changed linear trend for C. Still assuming single linear trends from cycle 236 for Ku and for C.	259 - 276
703	2000/04/03 2000-094	Begin use for cycle 279 onward	2000/04/04 2000-095	2000/04/04	The correction trends of MCR 701 were getting too large, and a temporary freeze was put in to hold values constant from 278 forward.	- -

Table 3-2 Sigma0 Related MCRs and File Release Form Information

From MCR Form			From File Release Form		Additional Information	
(1) MCR #	(2) MCR Origination Date	(3) Comments on MCR Form	(4) File Creation Date	(5) Release Approval Date	(6) Comments on MCR actions and reasons	(7) Cycles Distributed, This MCR
708	2000/07/18 2000-200	Begin use for cycle 288, reprocess 277-287; table change for cycle 236 forward, but cycles 236-276 won't be corrected at this time	2000/07/19 2000-201	2000/07/19	Side B trends (Ku particularly) show step-change at cycle 256; use two line segments (with step change at cycle 256) fitted to Cal 1 trends for producing Side B calibration table entries.	277 - 299
720	2000/12/06 2000-341	Begin use for cycle 303; reprocess sdr->IGDR for cycles 300-302	2000/12/07 2000-342	2000/12/07	Side B sigma0 trends have started to deviate from Cal 1 trends; now a three-segment line fit to sigma0 trends will be used for the Side B calibration table entries.	300 - 326
740	2000/09/17 2001-260	Begin use for cycle 327; reprocess IGDRs, GDRs for 327 forward	2001/09/17 2001-260	2001/09/17	The three-segment line fit (to sigma0 trends) was revised using data from approximately twenty cycles since the last trend fit, and a new set of Side B calibration table entries was produced.	327 - -

3.2.3 Brief Review of Side A Behavior and of Corrections in Side B

In TOPEX Side A there were indications that the time trend of the CAL-1 AGC differed from the time trend of the over-ocean cycle-averaged sigma0 in both the Ku- and the C-band systems. We were forced to use the time trend of the over-ocean sigma0 cycle-averages to produce the sigma0 Cal Table entries. We tried to make these corrections only for relatively long times, avoiding responding to cycle-to-cycle noise. Correcting a noisy process by making trend estimates projections is a frustrating activity at best, and the Side A Cal Table has several places where we failed to detect trend changes or to correct our trend projections soon enough. After TOPEX was switched to its Side B in early February 1999 we described the entire Side A Cal Table history in “TOPEX Sigma0 Calibration Table History for All Side A Data”, G. S. Hayne and D. W. Hancock III, 27 July 1999, available at http://topex.wff.nasa.gov/

docs/Sigma0Cal_A_All.pdf. In that paper we produced our best guess at what values the Cal Table should have included, based on a quadratic trend fit to the entire Side A set of over-ocean cycle-averages of sigma0.

When Side B was turned on, initial Side B Cal Table entries were chosen in a committee process (involving P.S. Callahan and others) so that there was no obvious discontinuity in over-ocean sigma0 from Side A to Side B. These initial Cal Table values were held constant for about a dozen cycles until trends became apparent.

The Side B C-band Cal Table values were changed beginning with cycle 248 to correct for an apparent downward trend in the C-band over-ocean sigma0. No corrections were made to the Side B Ku-band Cal Table until cycle 259 when it became clear that there was an upward trend in the Ku-band over-ocean sigma0. Both the Ku- and the C-band Cal Table values were produced by assuming a linear trend in the over-ocean sigma0. The Ku-band system was particularly surprising in showing an increase in over-ocean sigma0 estimates before correction. Eventually it became clear that the linear trends in the Cal Table were overcorrecting the data, and the Cal Table values were held constant until the data trends caught up with the correction; this Cal Table freeze was made at cycle 274 for Ku-band and at cycle 278 for C-band. At the end of cycle 287 we reassessed the trends, a new set of Cal Table values was produced, and the GDRs for cycles 277 - 284 were reprocessed and re-released. GDRs for cycles 285 through 299 were released only with the new Cal Table values.

Another trend estimate produced a new Cal Table which was used in processing cycles 300 through 326. This Cal Table was based on sigma0 trends rather than on Calibration Mode 1 AGC trends, a change which will be discussed further in the next section of this report. One final Cal Table adjustment was made in 2001, with a new table used in processing cycles 327 onward.

Table 3-3 summarizes the Side B Cal Table values used for the distributed GDRs. Column 1 of Table 3-3 is the data cycle number, and columns 2 and 3 give the Ku- and C-band Cal Table values which were used in producing the TOPEX GDR data product. Columns 4 and 5 give a current best estimate of the Side B Cal Table values based on a trend analysis of all side B sigma0_uncorr as discussed in the next sections.

3.2.4 Current Approach to Side B Corrections, Based on CAL-1

Figure 3-11 summarizes the Side B Ku-band altimeter's CAL-1, CAL-2, transmit power monitor, and over-ocean sigma0 cycle averages for cycles 236 - 345, and Figure 3-12 presents the corresponding information for the C-band altimeter. A small seasonal correction, derived from the entire set of Side A sigma0 data, has been applied to the over-ocean sigma0 averages. Notice that the Cal Table corrections have been removed from the over-ocean sigma0 in these figures, because the purpose is to see the trends in absence of Cal Table corrections. In Figure 3-11 and Figure 3-12 the CAL-1 delta AGC trend is fairly good agreement with the over-ocean sigma0 trend for cycles 236 through 300 or so. This trend agreement suggested that the CAL-1 AGC change would provide an adequate basis for the Side B Cal Table (unlike the Side A altimeter for which the CAL-1 trend differed from the over-ocean sigma0 trend). The CAL-1 AGC trends were used as the basis of Side B Cal Table values through cycle

302. For cycles 303 and higher the Cal Table values have been based on over-ocean sigma0 trends (as was done in Side A).

In Figure 3-11 there is an apparent step-change in both the Ku-band CAL-1 AGC and the Ku-band over-ocean sigma0. This step occurred at cycle 256, a SSALT cycle, during which a satellite safe hold occurred resulting in the TOPEX altimeter's being powered off during most of cycle 256 (cycle 256 started on 1999 day 238, 26 August). During a normal SSALT cycle the TOPEX altimeter is still powered but is in its standby mode. We don't know why but the TOPEX altimeter apparently behaved differently before and after this cycle 256 event. There is a visible step-change seen in Figure 3-11 "Ku Side B Cycle-Avg Cal-1 & Cal-2 Delta AGC, Sigma0" on page 3-16,

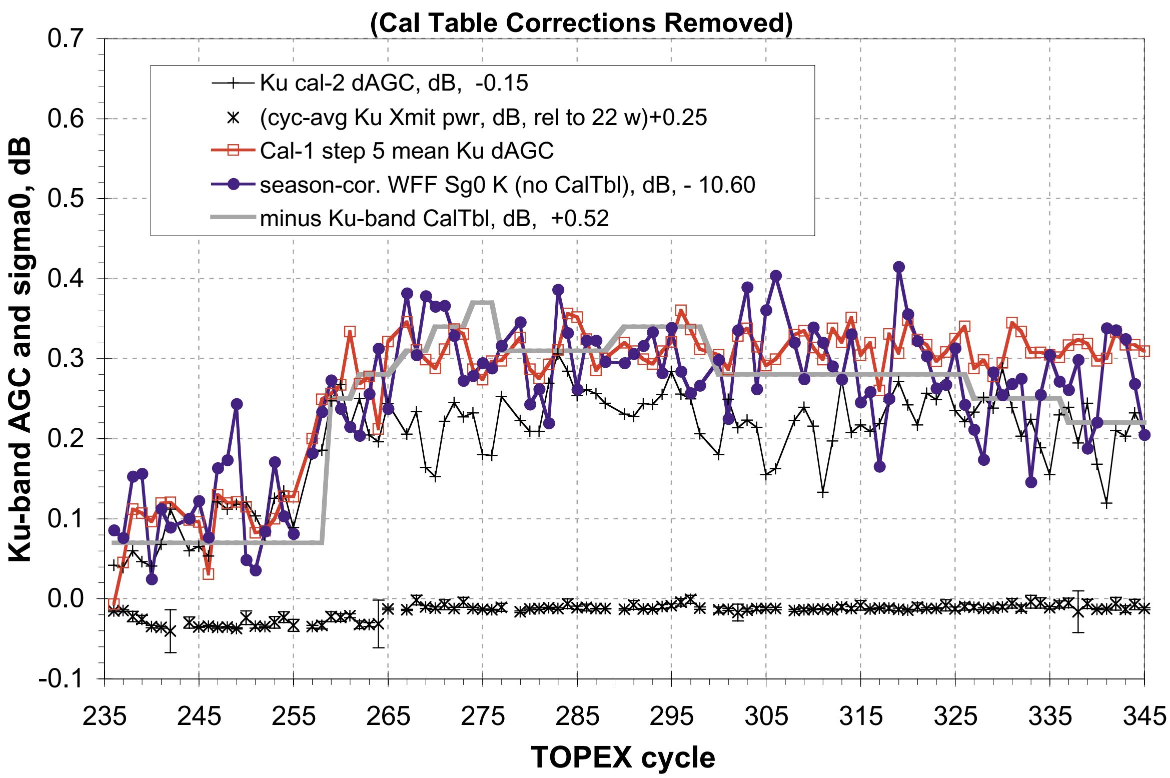


Figure 3-11 Ku Side B Cycle-Avg Cal-1 & Cal-2 Delta AGC, Sigma0

and there was also a change in the Ku-band altimeter's track acquisition behavior in land-to-water transitions. Before cycle 256 there were occasional cases of the Ku-band altimeter's requiring several tens of seconds for acquisition, but after the cycle 256 safe hold the Ku-band land-to-water track transitions no longer showed the occasional anomalous long acquisition times. For whatever unknown reason, the Side B altimeter behaves differently after the cycle 256 safe hold. The C-band altimeter Figure 3-12 "C-Band Side B Cyc-Avg Cal-1 & Cal-2 Delta AGC, Sigma0" on page 3-17 shows less magnitude of effect than the Ku-band Figure 3-11, but there does appear to be a small C-band step change at cycle 256 in Figure 3-12.

Another TOPEX satellite safe hold occurred on year 2000 day 329 (November 23). The TOPEX altimeter was off from about 04:45 to 23:19 of 2000d329 and, following com-

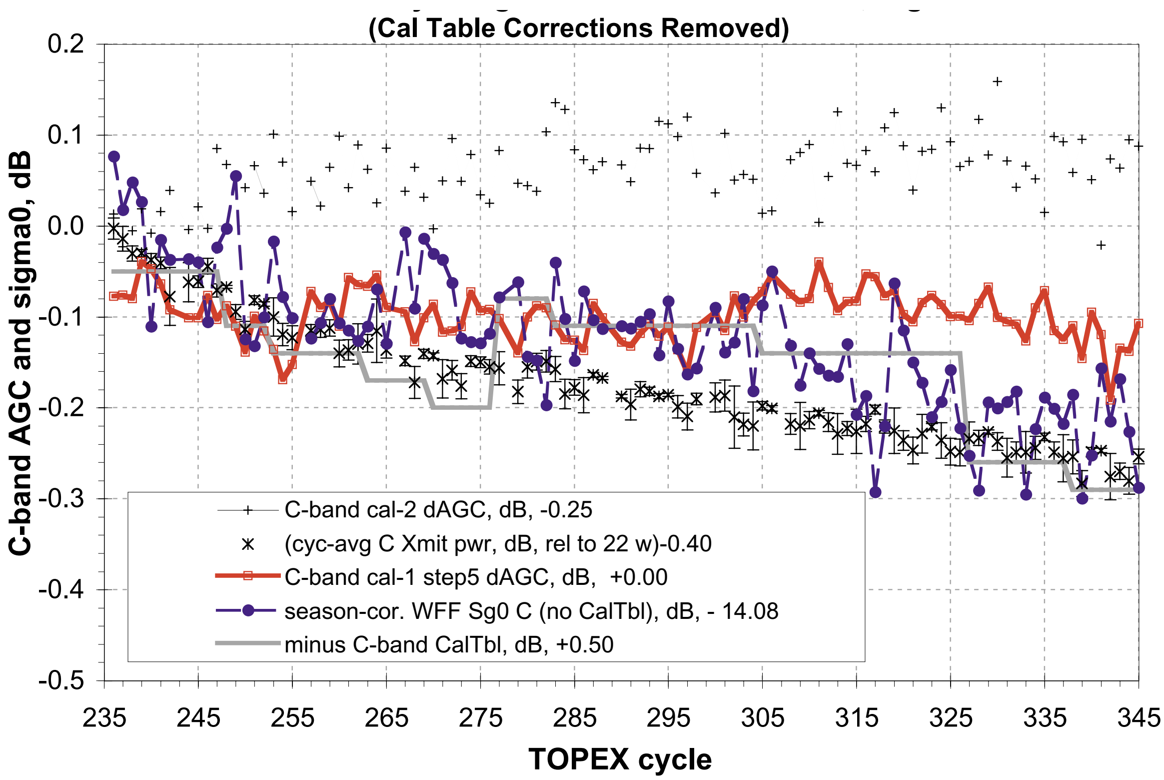


Figure 3-12 C-Band Side B Cyc-Avg Cal-1 & Cal-2 Delta AGC, Sigma0

manding and software reloading, was put back into track mode at 07:50 on 2000d330. The altimeter temperatures dropped during the safe hold, but normal operating conditions had been reached by the end of 2000d331. Unlike the cycle 256 safe hold, there were no apparent changes in the TOPEX AGC and sigma0 associated with the 2000d329 safe hold.

3.2.5 CAL-1 Fitted Trends for Estimation of Cal Table Values

Based on the divergence of the Side B C-Band CAL-1 and sigma0 trends in Figure 3-12, we decided to use the sigma0 trend as the basis for the Side B C-band sigma0 Cal Table values. For consistency, we decided also to use the Ku-band sigma0 trend for the Side B Ku-band sigma0 Cal Table. We decided to fit straight line segments to the Side B sigma0 data with a discontinuity in slope and value of the fit at cycle 256 to allow for the possible step change in altimeter characteristics; the sigma0 data after cycle 256 was modeled by two straight line segments having continuous values but allowing a discontinuity in the slope. The cycle at which the slope changed was one of the variable fit parameters, so the fits consisted of three straight-line segments with the latter two connected to each other. Figure 3-13 "TOPEX Side B Sigma0 Trends" shows the sigma0 and the fitted line segments for both Ku- and C-band for equally-weighted least-squares fitting.

The (negatives of) the Figure 3-13 data provide relative sigma0 corrections, and it was arbitrarily decided to set the relative corrections to zero at cycle 240; that is, we assumed that +0.45 dB was the correct Ku-band Cal Table value and that +0.55 dB

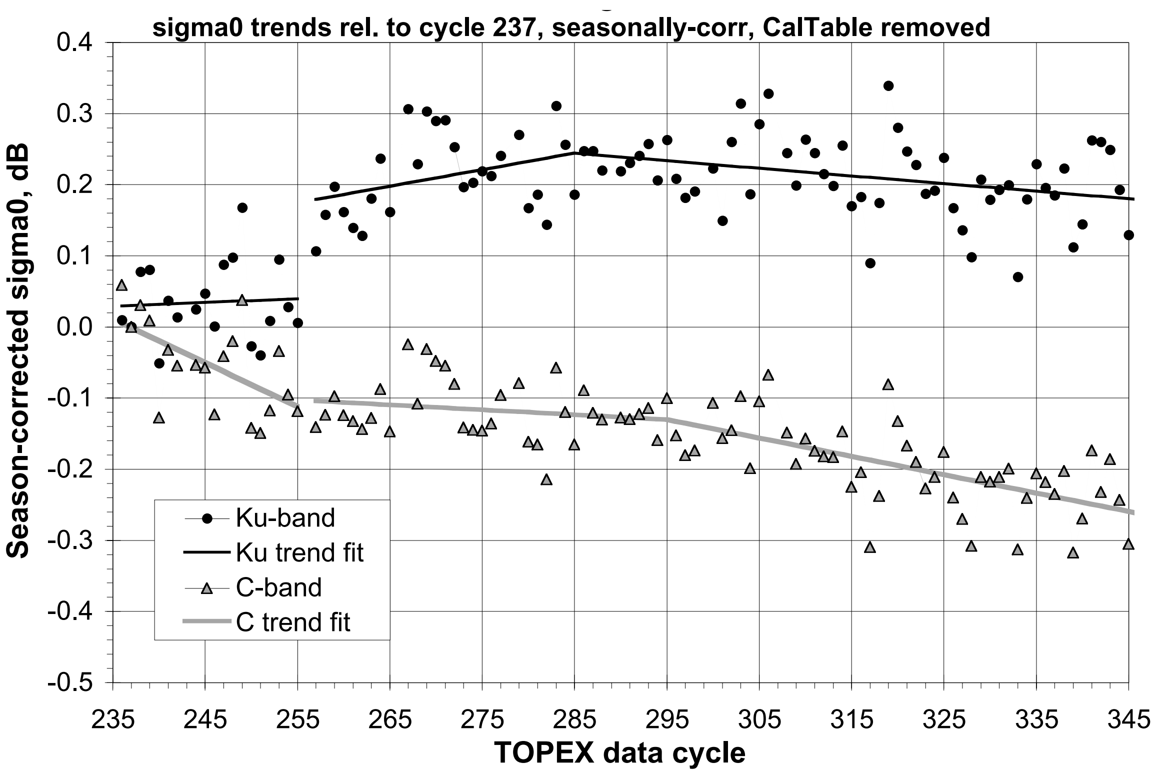


Figure 3-13 TOPEX Side B Sigma0 Trends

was the correct C-band Cal Table value at cycle 240. One additional detail is that the Cal Table entries have been quantized at an arbitrarily chosen 0.03 dB level.From the line-segment fits and the quantization choice we then calculated the values given in columns 4 and 5 of Table 3-3. These are our best current guess at the values that

Table 3-3 TOPEX Sigma0 Cal Table Values, in dB

TOPEX Data Cycle	Ku-band Cal Table Value Used for GDR	C-band Cal Table Value Used for GDR	New Ku-band Cal Table Value	New C-band Cal Table Value
236	0.45	0.55	0.45	0.52
237	0.45	0.55	0.45	0.52
238	0.45	0.55	0.45	0.55
239	0.45	0.55	0.45	0.55
240	0.45	0.55	0.45	0.55
241	0.45	0.55	0.45	0.55
242	0.45	0.55	0.45	0.55
244	0.45	0.55	0.45	0.58
245	0.45	0.55	0.45	0.58

Table 3-3 TOPEX Sigma0 Cal Table Values, in dB (Continued)

TOPEX Data Cycle	Ku-band Cal Table Value Used for GDR	C-band Cal Table Value Used for GDR	New Ku-band Cal Table Value	New C-band Cal Table Value
246	0.45	0.55	0.45	0.58
247	0.45	0.55	0.45	0.58
248	0.45	0.61	0.45	0.61
249	0.45	0.61	0.45	0.61
250	0.45	0.61	0.45	0.61
251	0.45	0.61	0.45	0.61
252	0.45	0.61	0.45	0.61
253	0.45	0.64	0.45	0.64
254	0.45	0.64	0.45	0.64
255	0.45	0.64	0.45	0.64
257	0.45	0.64	0.30	0.64
258	0.45	0.64	0.30	0.64
259	0.27	0.64	0.30	0.64
260	0.27	0.64	0.30	0.64
261	0.27	0.64	0.30	0.64
262	0.24	0.64	0.30	0.64
263	0.24	0.67	0.30	0.64
264	0.24	0.67	0.30	0.64
265	0.24	0.67	0.27	0.64
267	0.21	0.67	0.27	0.64
268	0.21	0.67	0.27	0.64
269	0.21	0.67	0.27	0.64
270	0.18	0.70	0.27	0.64
271	0.18	0.70	0.27	0.64
272	0.18	0.70	0.27	0.64
273	0.18	0.70	0.27	0.64
274	0.15	0.70	0.27	0.64
275	0.15	0.70	0.27	0.64
276	0.15	0.70	0.27	0.64

Table 3-3 TOPEX Sigma0 Cal Table Values, in dB (Continued)

TOPEX Data Cycle	Ku-band Cal Table Value Used for GDR	C-band Cal Table Value Used for GDR	New Ku-band Cal Table Value	New C-band Cal Table Value
277	0.21	0.58	0.27	0.64
279	0.21	0.58	0.24	0.64
280	0.21	0.58	0.24	0.64
281	0.21	0.58	0.24	0.64
282	0.21	0.58	0.24	0.64
283	0.21	0.61	0.24	0.64
284	0.21	0.61	0.24	0.64
285	0.21	0.61	0.24	0.64
286	0.21	0.61	0.24	0.64
287	0.21	0.61	0.24	0.67
288	0.21	0.61	0.24	0.67
290	0.18	0.61	0.24	0.67
291	0.18	0.61	0.24	0.67
292	0.18	0.61	0.24	0.67
293	0.18	0.61	0.24	0.67
294	0.18	0.61	0.24	0.67
295	0.18	0.61	0.24	0.67
296	0.18	0.61	0.24	0.67
297	0.18	0.61	0.24	0.67
298	0.18	0.61	0.24	0.67
300	0.24	0.61	0.24	0.67
301	0.24	0.61	0.24	0.67
302	0.24	0.61	0.27	0.67
303	0.24	0.61	0.27	0.67
304	0.24	0.61	0.27	0.67
305	0.24	0.64	0.27	0.70
306	0.24	0.64	0.27	0.70
308	0.24	0.64	0.27	0.70
309	0.24	0.64	0.27	0.70

Table 3-3   TOPEX Sigma0 Cal Table Values, in dB (Continued)

TOPEX Data Cycle	Ku-band Cal Table Value Used for GDR	C-band Cal Table Value Used for GDR	New Ku-band Cal Table Value	New C-band Cal Table Value
310	0.24	0.64	0.27	0.70
311	0.24	0.64	0.27	0.70
312	0.24	0.64	0.27	0.70
313	0.24	0.64	0.27	0.70
314	0.24	0.64	0.27	0.70
315	0.24	0.64	0.27	0.70
316	0.24	0.64	0.27	0.73
317	0.24	0.64	0.27	0.73
318	0.24	0.64	0.27	0.73
319	0.24	0.64	0.27	0.73
320	0.24	0.64	0.27	0.73
321	0.24	0.64	0.27	0.73
322	0.24	0.64	0.27	0.73
323	0.24	0.64	0.27	0.73
324	0.24	0.64	0.27	0.73
325	0.24	0.64	0.27	0.73
326	0.24	0.64	0.27	0.73
327	0.27	0.76	0.27	0.73
328	0.27	0.76	0.27	0.76
329	0.27	0.76	0.27	0.76
330	0.27	0.76	0.30	0.76
331	0.27	0.76	0.30	0.76
332	0.27	0.76	0.30	0.76
333	0.27	0.76	0.30	0.76
334	0.27	0.76	0.30	0.76
335	0.27	0.76	0.30	0.76
336	0.27	0.76	0.30	0.76
337	0.30	0.76	0.30	0.76
338	0.30	0.79	0.30	0.76

Table 3-3 TOPEX Sigma0 Cal Table Values, in dB (Continued)

TOPEX Data Cycle	Ku-band Cal Table Value Used for GDR	C-band Cal Table Value Used for GDR	New Ku-band Cal Table Value	New C-band Cal Table Value
339	0.30	0.79	0.30	0.76
340	0.30	0.79	0.30	0.79
341	0.30	0.79	0.30	0.79
342	0.30	0.79	0.30	0.79
343	0.30	0.79	0.30	0.79
344	0.30	0.79	0.30	0.79
345	0.30	0.79	0.30	0.79
346			0.30	0.79
347			0.30	0.79
348			0.30	0.79
349			0.30	0.79
350			0.30	0.79
351			0.30	0.82
352			0.30	0.82
353			0.30	0.82
354			0.30	0.82
355			0.30	0.82
356			0.30	0.82
357			0.30	0.82
358			0.33	0.82
359			0.33	0.82
360			0.33	0.82
361			0.33	0.82
362			0.33	0.82
363			0.33	0.85
364			0.33	0.85
365			0.33	0.85
366			0.33	0.85
367			0.33	0.85

Table 3-3 TOPEX Sigma0 Cal Table Values, in dB (Continued)

TOPEX Data Cycle	Ku-band Cal Table Value Used for GDR	C-band Cal Table Value Used for GDR	New Ku-band Cal Table Value	New C-band Cal Table Value
368			0.33	0.85
369			0.33	0.85
370			0.33	0.85
371			0.33	0.85
372			0.33	0.85
373			0.33	0.85
374			0.33	0.85
375			0.33	0.88

should have been in the Cal Table, and if one were to recalculate GDRs one should use the column 4 and 5 numbers as replacements for the values in columns 2 and 3 which were used in the original GDR production. The old Cal Table values, the fitted line-segments, and the quantized new Cal Table values are plotted for Ku-band in Figure 3-14 "TOPEX Side B Old and New Ku-band Cal Table Values" on page 3-23

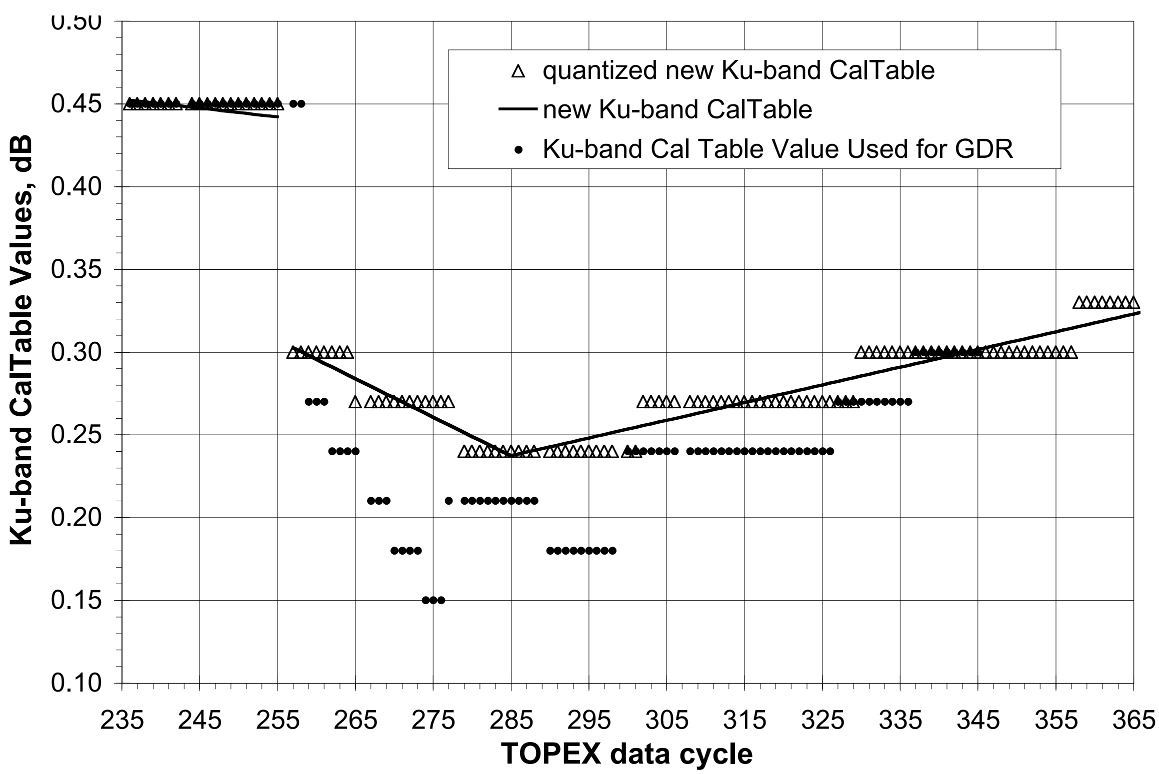


Figure 3-14 TOPEX Side B Old and New Ku-band Cal Table Values

and for C-band in Figure 3-15 "TOPEX Side B Old and New C-band Cal Table Values" on page 3-24. These figures show the CalTable values out through to cycle 365 by sim-

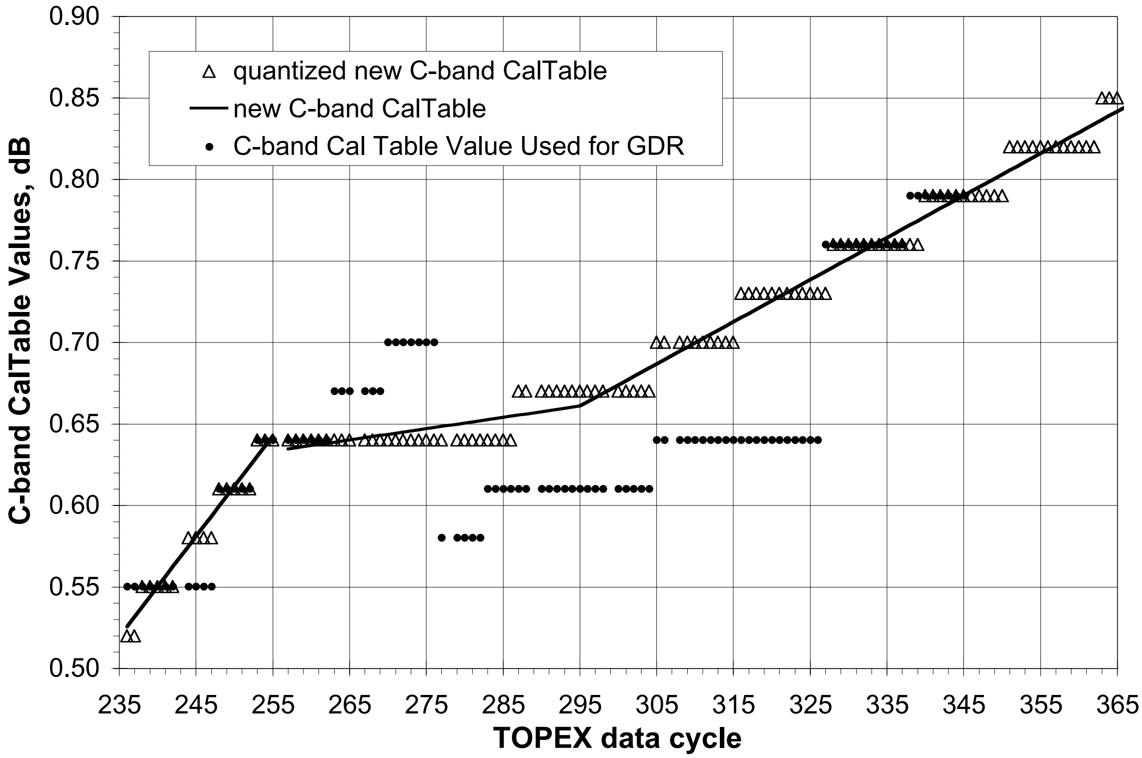


Figure 3-15 TOPEX Side B Old and New C-band Cal Table Values

ple extrapolation of the last linear fit segments. Figure 3-14 shows that the Ku-band sigma0 values for cycles 257 and 258 are the most in need of additional adjustment, because no change in the Ku Cal Table had been made from start of Side B until cycle 259.

We continually monitor the altimeter's power-related trends, and we document these trends at the web site http://topex.wff.nasa.gov/docs/docs.html.

3.3 Side B Point Target Response

Changes in the TOPEX Side A altimeter became apparent around the middle of 1998. The first symptoms of the changes were an increase in the altimeter's SWH estimates and an increase in the range rms. Subsequent investigation revealed apparent changes in the altimeter's point target response (PTR); these changes were shown by the waveform data in the altimeter's Calibration Mode 1 (CAL-1). The Side A PTR changes were the reason that the altimeter was switched to its Side B in February 1999 near the start of cycle 236.

The normal TOPEX CAL-1 has been executed at least twice daily throughout the entire TOPEX operation. In CAL-1 a portion of the transmitted signal is fed back into the altimeter receiver through a special calibration attenuator and the altimeter tracks this transmitted signal using a special tracking algorithm. During the preflight testing a special calibration mode sweep test (the CalSweep) had been developed in which the altimeter did not automatically track the PTR; instead the AGC level was frozen at a preset level and the altimeter's fine-height word was incremented through its entire range (equivalent to 8 waveform sample positions). The CalSweep waveforms can be processed to give a "fine-grained" look at the PTR. After the Side A overestimates of SWH became apparent, a software patch was uploaded to TOPEX to allow the CalSweep to be executed on-orbit. The CalSweep was executed approximately monthly from mid-1998 through the end of the Side A operation. The year 1998 Engineering Assessment Update (published in August 1999) contains a more detailed discussion of the Side A PTR observation by CAL-1 and CalSweep, and the consequences of the Side A PTR change.

The CalSweep has continued to be executed about once a month for the entire time of Side B operation. Figure 3-16 "TOPEX Side B Ku-Band Cal Sweep 2001 Day 340" on page 3-25 shows the comparison of an early Side B CalSweep (1999 day 042) and the

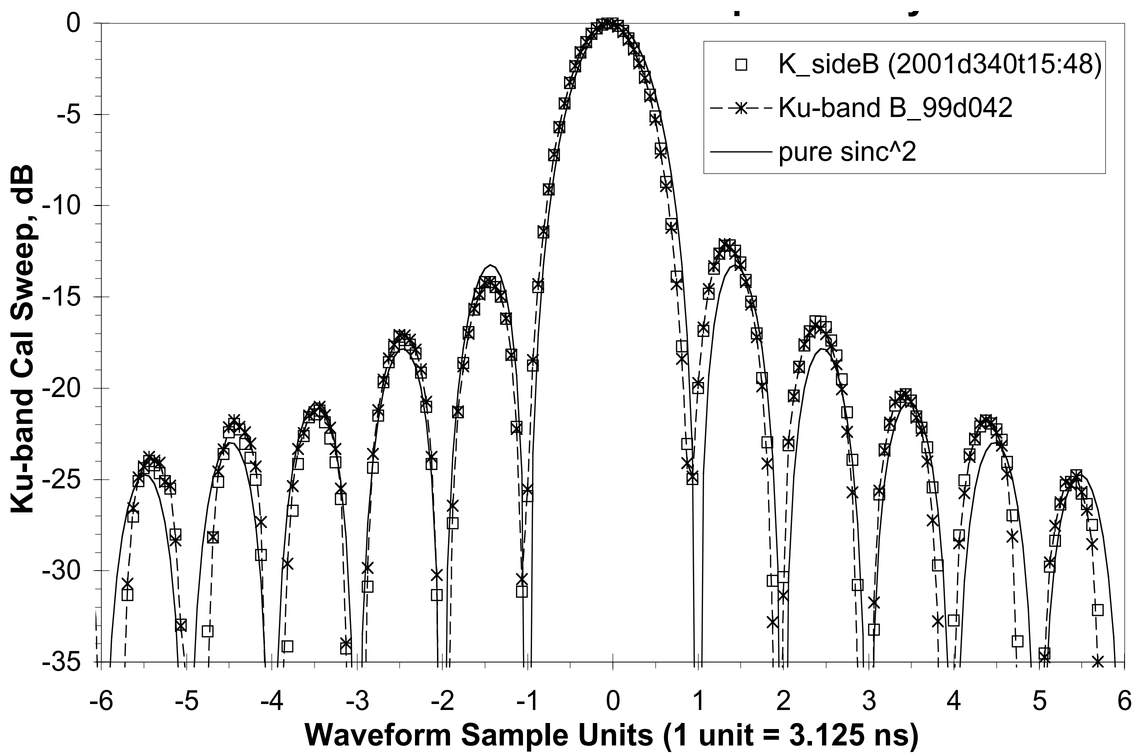


Figure 3-16 TOPEX Side B Ku-Band Cal Sweep 2001 Day 340

last Ku-band CalSweep of year 2001 (2001 day 340). Figure 3-17 "TOPEX Side B C-Band Cal Sweep 2001 Day 340" on page 3-26 shows the same comparison for the Side B C-band altimeter. As a reference, the theoretical model for the PTR is shown by the pure sinc2 plotted in Figure 3-16 and Figure 3-17. Only the central lobe and the first five sidelobes are shown in these figures. To within the accuracy and repeatability of the CalSweep, there has been practically no perceptible change in the Side B Ku- and

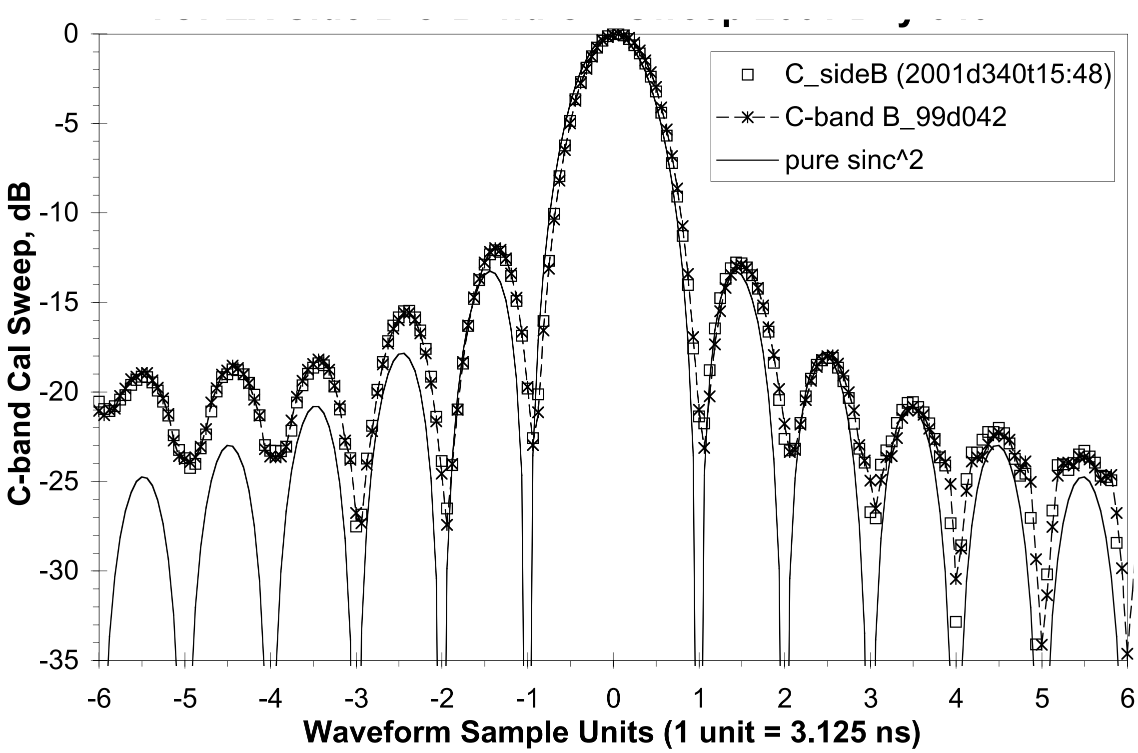


Figure 3-17 TOPEX Side B C-Band Cal Sweep 2001 Day 340

C-band CalSweeps from start of Side B through the end of year 2001. If there have been any changes at all in the Side B CalSweeps, these changes have been less than the size of the plot symbols in Figure 3-16 and Figure 3-17.

In addition to the CalSweep, further information on the PTR is available from the waveform data in the normal CAL-1 which is executed about twenty times in each TOPEX repeat cycle. While the CalSweep “paints” the PTR in fine-grained detail, the CAL-1 waveform provides only a single sample at about the peak of each of the PTR sidelobes. We keep a database of waveforms from the first two CAL-1 modes in each repeat cycle, and this provides another way of assessing possible PTR changes as a function of cycle. We will use the CAL-1 step 5 waveforms for the following discussion because the AGC level of step 5 is about the same level as in the TOPEX normal over-ocean fine track.

For the TOPEX Side B Ku-band system, Figure 3-18 "Side B Ku Cal-1 Lower Sidelobes Relative to Peak Value" on page 3-27 shows the time history of the first five PTR lobes below the main peak and Figure 3-19 "Side B Ku Cal-1 Higher Sidelobes Relative to Peak Value" shows the first five lobes above the main peak. These two figures show the Ku-band data from start of Side B operation through the end of year 2001, and none of the sidelobe peak values exhibit any significant time trend. For the Side B C-band system, Figure 3-20 "Side B C Cal-1 Lower Sidelobes Relative to Peak Value" on page 3-28 shows the first five PTR lobes below the main peak and Figure 3-21 "Side B C Cal-1 Higher Sidelobes Relative to Peak Value" on page 3-28 shows the first five sidelobes above the main peak. While the lower five C-band Side B PTR sidelobes in

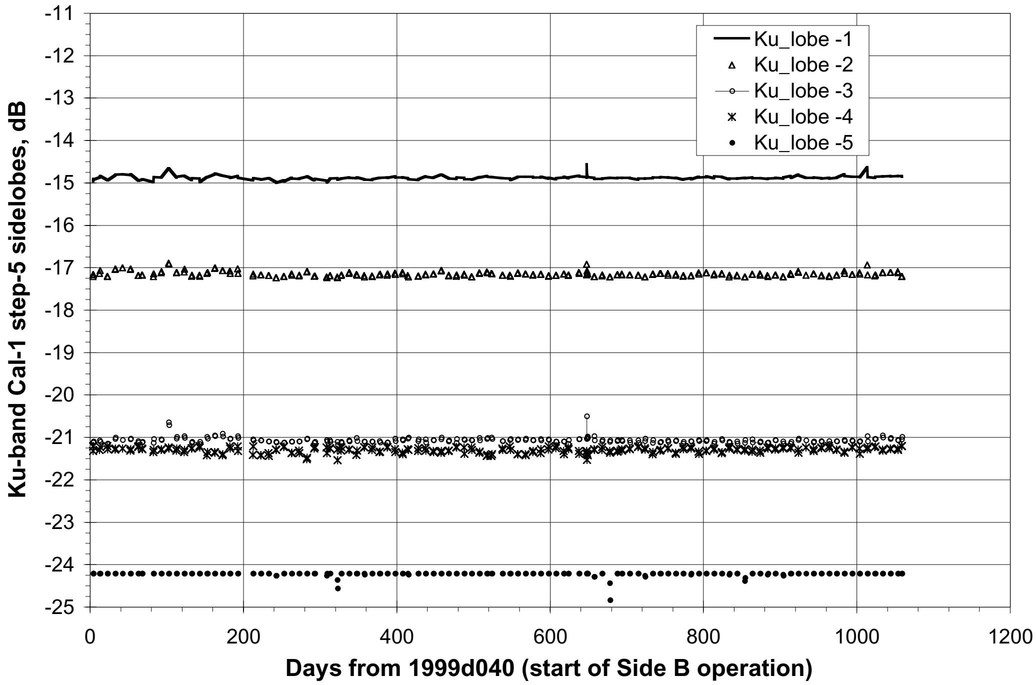


Figure 3-18 Side B Ku Cal-1 Lower Sidelobes Relative to Peak Value

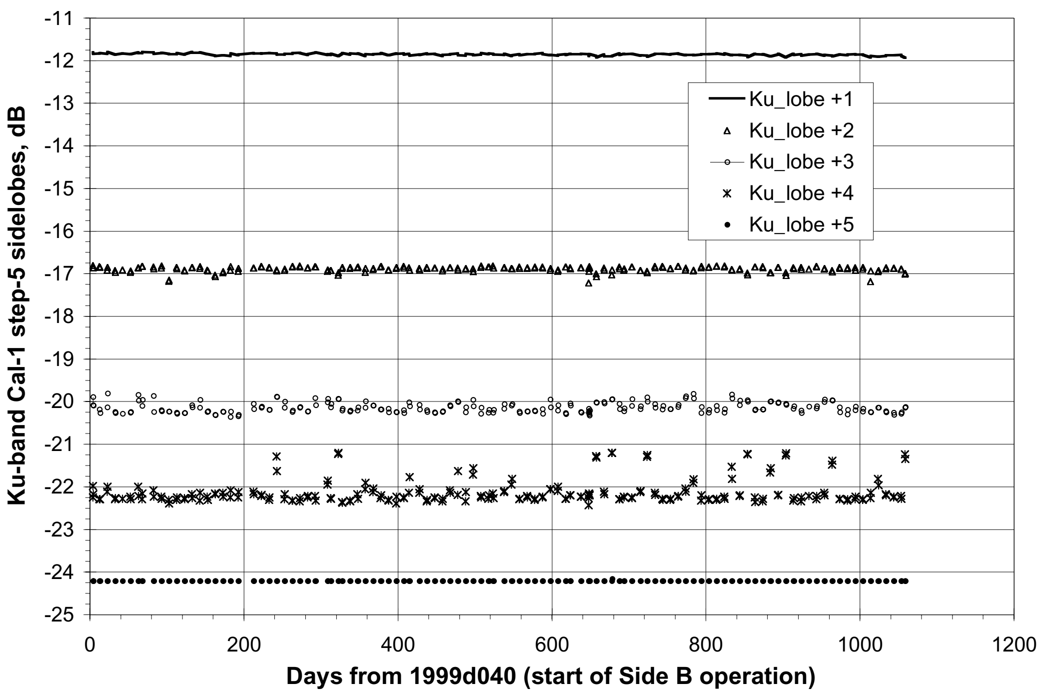


Figure 3-19 Side B Ku Cal-1 Higher Sidelobes Relative to Peak Value

Figure 3-20 show no significant time trends, there are possible small trends in a couple of the upper five C-band sidelobes in Figure 3-21. The +2 sidelobe shows an increase of about a quarter dB from start of Side B through the end of year 2001, and the +3 sidelobe shows about an increase for about half dB over this time. Figure 3-21

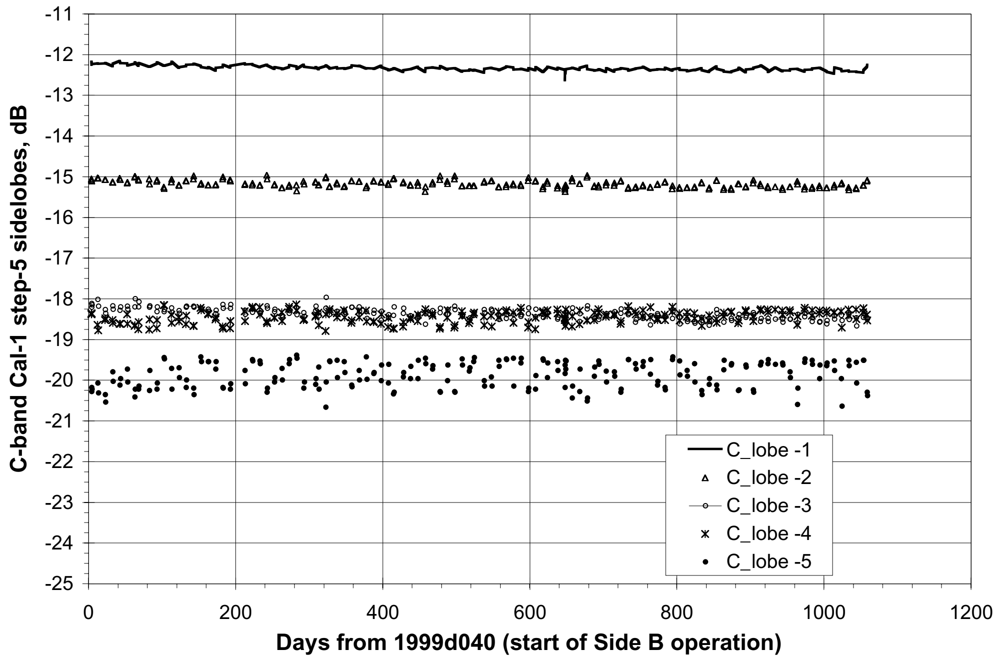


Figure 3-20 Side B C Cal-1 Lower Sidelobes Relative to Peak Value

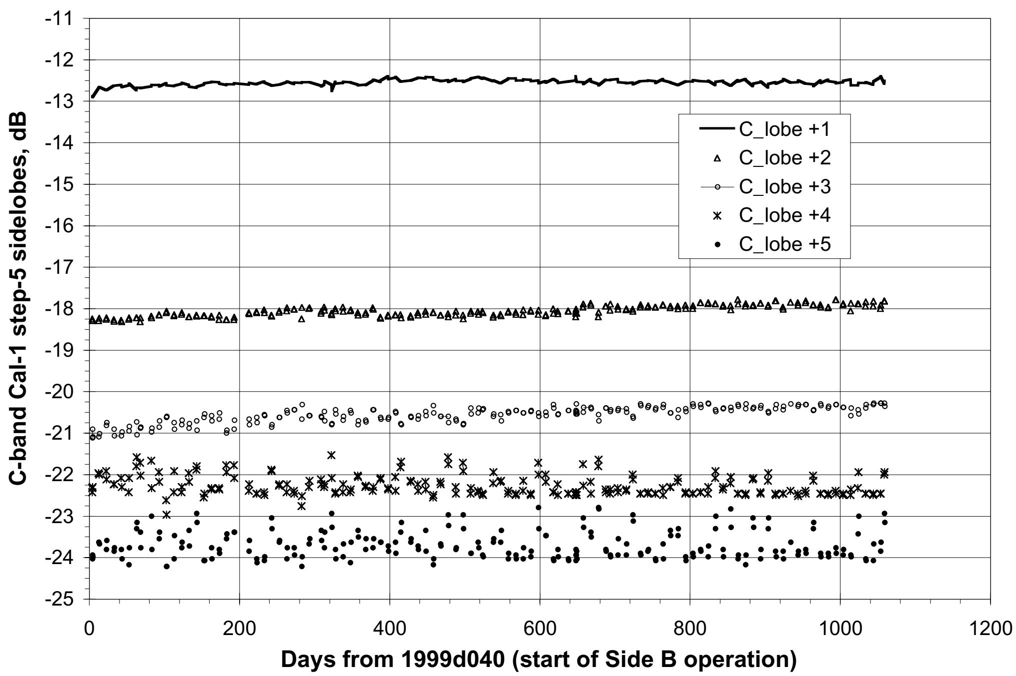


Figure 3-21 Side B C Cal-1 Higher Sidelobes Relative to Peak Value

may possibly show a step change in these sidelobes at the cycle 256 safehold about 208 days after the start of Side B operation. We think that these changes are too small to have any practical consequences in the TOPEX range or SWH estimation, but future CalSweep and CAL-1 waveform trend results will be closely watched for possible further changes.

Section 4

Ancillary Performance Assessments

4.1 Range Measurement Noise

The TOPEX altimeter white noise levels have been evaluated using a technique, based on high-pass filtering of 1-Hz sea surface height time series, as described in Section 4.2 of the "TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2001, June 2001. This filtering technique isolates the portion of the spectrum that should be dominated by the white noise floor and interpreted as the contribution of the instrument noise. It is simpler to use than repeat track-sampling comparisons, allows to analyze much larger amounts of data and in this way it is more efficient in estimating the noise. This monitoring of the noise level of the altimeter over time should help to detect hardware changes.

The noise level estimates provided in Table 4-1 show stable characteristics from cycle-to-cycle with the basic linear dependence of the noise level upon significant wave-height (SWH). The TOPEX altimeter noise level is estimated to be about 1.8 cm for a 2 m SWH, as shown in Figure 4-1, when solving the fitted equation.

Note: Cycles 243, 256, 266, 278, 289, 299, and 307 were left out because they are from CNES SSalt.

Table 4-1 Statistical Indicators Based on 1-Minute Track Segments

Time Period	SWH (m)		Noise Level (cm)		
Cycle	Mean	STD	Mean	STD	at 2m SWH
236	2.846	1.219	2.204	0.803	1.806
237	2.840	1.314	2.168	0.798	1.784
238	2.763	1.129	2.152	0.735	1.807
239	2.789	1.235	2.151	0.769	1.789
240	3.054	1.342	2.327	0.887	1.815
241	2.951	1.203	2.220	0.755	1.803
242	2.861	1.249	2.163	0.743	1.789
244	2.895	1.430	2.195	0.830	1.800
245	2.863	1.435	2.203	0.859	1.806
246	2.891	1.390	2.221	0.829	1.814
247	2.949	1.417	2.268	0.870	1.833
248	2.873	1.429	2.204	0.842	1.813

Table 4-1 Statistical Indicators Based on 1-Minute Track Segments (Continued)

Time Period	SWH (m)		Noise Level (cm)		
Cycle	Mean	STD	Mean	STD	at 2m SWH
249	2.679	1.261	2.108	0.745	1.820
250	2.984	1.574	2.248	0.885	1.808
251	3.049	1.493	2.284	0.887	1.800
252	2.931	1.478	2.233	0.870	1.814
253	2.784	1.334	2.153	0.772	1.811
254	2.843	1.486	2.185	0.869	1.795
255	2.940	1.494	2.223	0.866	1.796
257	2.845	1.381	2.177	0.797	1.804
258	3.031	1.449	2.272	0.849	1.806
259	2.786	1.407	2.161	0.849	1.794
260	2.931	1.460	2.261	0.888	1.818
261	2.913	1.387	2.207	0.833	1.788
262	2.811	1.294	2.157	0.776	1.796
263	2.808	1.258	2.162	0.745	1.809
264	2.719	1.204	2.127	0.737	1.808
265	2.677	1.191	2.087	0.721	1.791
267	2.651	1.238	2.104	0.792	1.786
268	2.707	1.270	2.136	0.799	1.800
269	2.599	1.227	2.069	0.761	1.790
270	2.634	1.141	2.065	0.664	1.809
271	2.692	1.198	2.129	0.756	1.804
272	2.761	1.251	2.139	0.752	1.807
273	2.903	1.295	2.230	0.847	1.786
274	2.961	1.323	2.241	0.798	1.812
275	2.955	1.314	2.231	0.805	1.791
276	2.935	1.327	2.243	0.833	1.805

Table 4-1 Statistical Indicators Based on 1-Minute Track Segments (Continued)

Time Period	SWH (m)		Noise Level (cm)		
Cycle	Mean	STD	Mean	STD	at 2m SWH
277	2.968	1.274	2.247	0.830	1.796
279	2.834	1.293	2.166	0.778	1.793
280	2.898	1.313	2.196	0.790	1.803
281	2.907	1.438	2.221	0.871	1.795
282	3.055	1.565	2.336	0.936	1.836
283	2.723	1.335	2.117	0.784	1.798
284	2.832	1.291	2.185	0.811	1.799
285	2.824	1.360	2.149	0.801	1.784
286	2.879	1.450	2.206	0.845	1.805
287	2.793	1.356	2.152	0.794	1.806
288	2.918	1.460	2.231	0.865	1.811
290	2.892	1.436	2.192	0.824	1.799
291	2.890	1.456	2.208	0.872	1.791
292	2.883	1.384	2.195	0.816	1.796
293	2.756	1.403	2.155	0.817	1.810
294	2.811	1.422	2.174	0.833	1.800
295	2.861	1.378	2.175	0.806	1.790
296	2.932	1.355	2.211	0.785	1.815
297	2.816	1.287	2.145	0.746	1.801
298	2.793	1.269	2.152	0.779	1.803
300	2.616	1.193	2.098	0.745	1.814
301	2.799	1.240	2.161	0.779	1.788
302	2.737	1.139	2.117	0.712	1.794
303	2.676	1.233	2.109	0.770	1.793
304	2.895	1.313	2.202	0.810	1.787
305	2.765	1.179	2.138	0.746	1.789

Table 4-1 Statistical Indicators Based on 1-Minute Track Segments (Continued)

Time Period	SWH (m)		Noise Level (cm)		
Cycle	Mean	STD	Mean	STD	at 2m SWH
306	2.686	1.204	2.119	0.761	1.801
308	2.756	1.130	2.123	0.716	1.784
309	2.785	1.178	2.140	0.725	1.792
310	2.726	1.131	2.114	0.699	1.798
311	2.802	1.273	2.187	0.781	1.820
312	2.931	1.316	2.245	0.840	1.806
313	2.897	1.322	2.188	0.799	1.795
314	2.872	1.291	2.186	0.775	1.810
315	2.975	1.302	2.216	0.789	1.781
316	2.906	1.331	2.206	0.810	1.803
317	2.890	1.287	2.191	0.780	1.790
318	2.947	1.466	2.253	0.894	1.803
319	2.774	1.327	2.182	0.814	1.832
320	2.720	1.309	2.124	0.773	1.806
321	2.738	1.335	2.133	0.773	1.809
322	2.781	1.274	2.135	0.743	1.801
323	2.934	1.523	2.223	0.873	1.803
324	2.973	1.432	2.237	0.840	1.801
325	2.904	1.508	2.235	0.903	1.808
326	2.875	1.437	2.190	0.841	1.795
327	3.053	1.473	2.274	0.870	1.794
328	2.853	1.426	2.172	0.824	1.790
329	2.820	1.324	2.166	0.766	1.808
330	2.866	1.507	2.207	0.894	1.796
331	3.156	1.450	2.321	0.858	1.790
332	2.942	1.353	2.206	0.788	1.803

Table 4-1 Statistical Indicators Based on 1-Minute Track Segments (Continued)

Time Period	SWH (m)		Noise Level (cm)		
Cycle	Mean	STD	Mean	STD	at 2m SWH
333	2.980	1.362	2.237	0.825	1.780
334	2.835	1.257	2.197	0.773	1.812
335	2.643	1.156	2.084	0.711	1.796
336	2.758	1.182	2.134	0.724	1.803
337	2.861	1.189	2.174	0.770	1.771
338	2.607	1.065	2.048	0.655	1.787
339	2.728	1.116	2.096	0.670	1.790
340	2.724	1.080	2.106	0.654	1.807
341	2.637	1.071	2.066	0.671	1.795
342	2.707	1.151	2.147	0.733	1.827

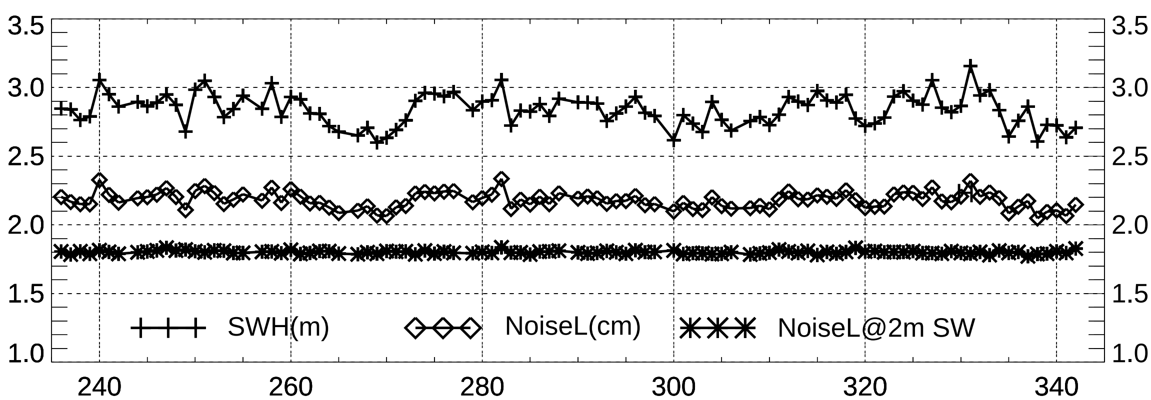


Figure 4-1 Plot of Selected Statistical Indicators from Table 4-1

4.2 Differencing as a Continuing System Health Monitor

An ancillary method of performance analysis we use is the differencing of parameters. The method has proven to be effective in verifying system stability.

Figure 4-2 "Cycle-Average SWH Delta in Meters" plots cycle averages of the C-band minus Ku-band significant waveheight difference, from the initial turn-on of Side B to the end of year 2001. The entire range of the delta SWHs is very small, only about 0.05 meters, and we expect to use the delta SWH cycle-averages as a continuing system health monitor rather than as a product having any particular science usefulness.

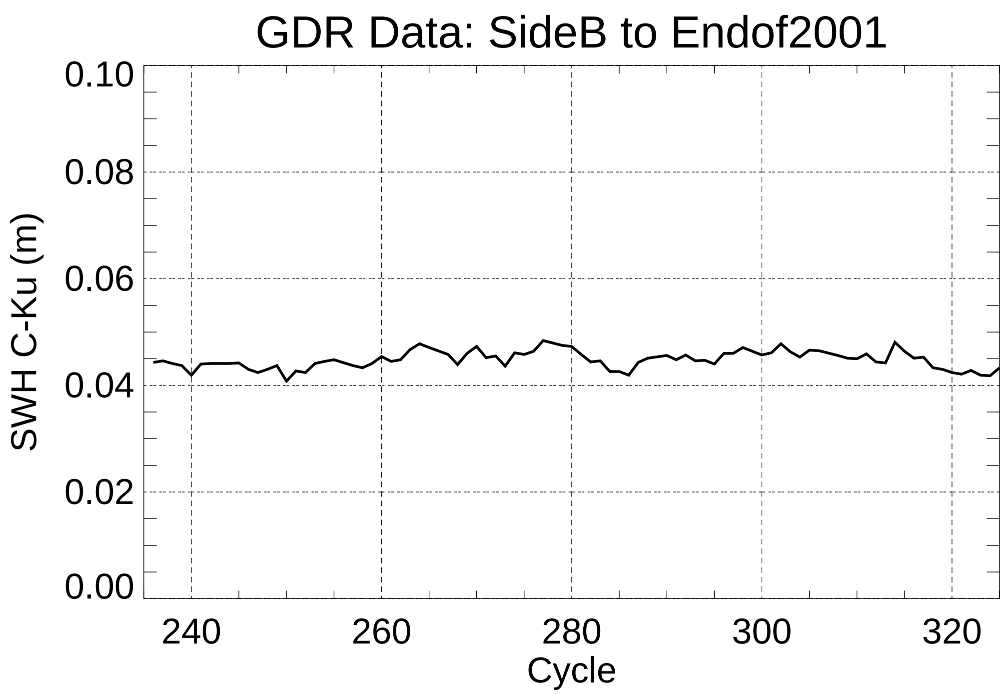


Figure 4-2 Cycle-Average SWH Delta in Meters

Figure 4-3 "Cycle-Average Gate Index Delta" plots cycle averages of the gate index delta, the difference between the secondary (C-band) and the primary (Ku-band) gate index, from Side B turn-on to the end of year 2001. The secondary gate is designated in the plot as SC, and the primary gate is PR. We see a small and sufficiently steady difference between the gate selection for each of the two frequencies. This figure is again a system health monitor.

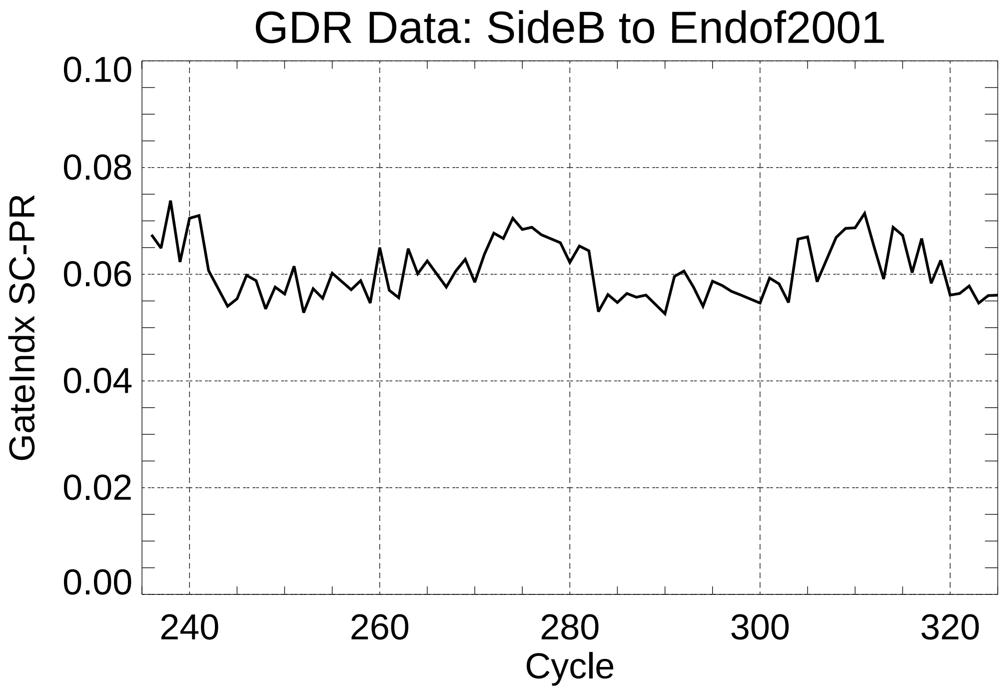


Figure 4-3 Cycle-Average Gate Index Delta

Figure 4-4 "Cycle-Average Sigma0 Delta in dB" plots the sigma0 difference, C-band minus Ku-band, from Side B turn-on to the end of year 2001. This plot provides a quick indication that the sigma0 calibration has been maintained to within 0.25 dB. Unlike the previous two figures, however, this figure is not a pure indication of system health, because both the Ku- and the C-band sigma0 calibrations have been adjusted during ground processing at the beginning of a number of different cycles throughout the TOPEX mission. For those few groups in the world using the sigma0 difference, relating it to rainfall estimation for instance, we strongly recommend that our TOPEX web site (topex.wff.nasa.gov) be visited. At that web site, we have provided a history of the sigma0 calibration changes as well as a possible set of sigma0 calibration adjustments to be applied to the distributed GDR sigma0 values.

Some of the relatively abrupt changes in Figure 4-4 are the result of various manual tweaking and adjustment of the sigma0 CalTable throughout the TOPEX mission. Section 3.2 of this report discusses the TOPEX processing system’s Cal Table that adjusts the sigma0 estimates for the effects of possible drifts or trends in the altimeter’s power estimation. As discussed in that section, it is possible to reassess the

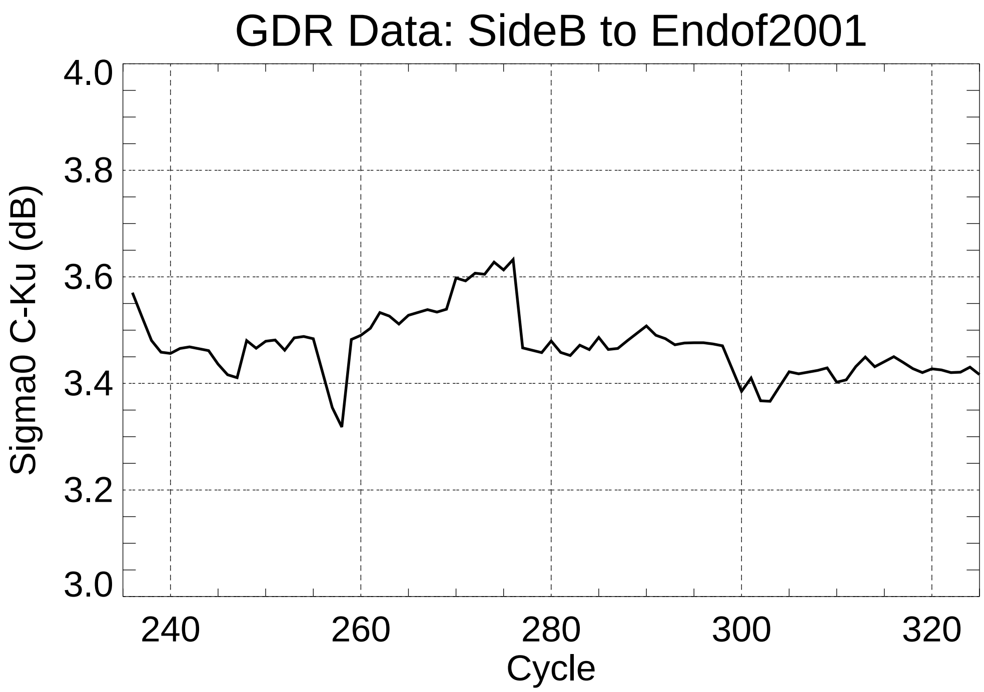


Figure 4-4 Cycle-Average Sigma0 Delta in dB

trends and to produce an estimate of a "better guess" set of values that one might wish had it been used instead of the actual Cal Table values in the GDR production.

The Side A sigma0 calibration history and our current best estimate of Side A sigma0 adjustments is described in "TOPEX Sigma0 Calibration Table History for All Side A Data", by G.S. Hayne and D.W. Hancock III, July 27, 1999, available at our TOPEX documents web location http://topex.wff.nasa.gov/docs.html. An interim Side B calibration history and set of adjustments is available from "TOPEX Side B Sigma0 Calibration Table Adjustments: February 2001 Update", by G.S. Hayne and D.W. Hancock III, February 15, 2001, also available at http://topex.wff.nasa.gov/docs.html.

A set of cycle-by-cycle adjustments of the sigma0 difference (C- minus Ku-band) was obtained from the Side B calibration history documents just described, and these adjustments were applied to the sigma0 differences (as plotted in Figure 4-4) to produce the result shown in Figure 4-5. Figure 4-5 plots the sigma0 difference (C minus Ku) based on our best current estimate of the values that should have been in the sigma0 Cal Table. Figure 4-5 appears somewhat smoother than Figure 4-4.

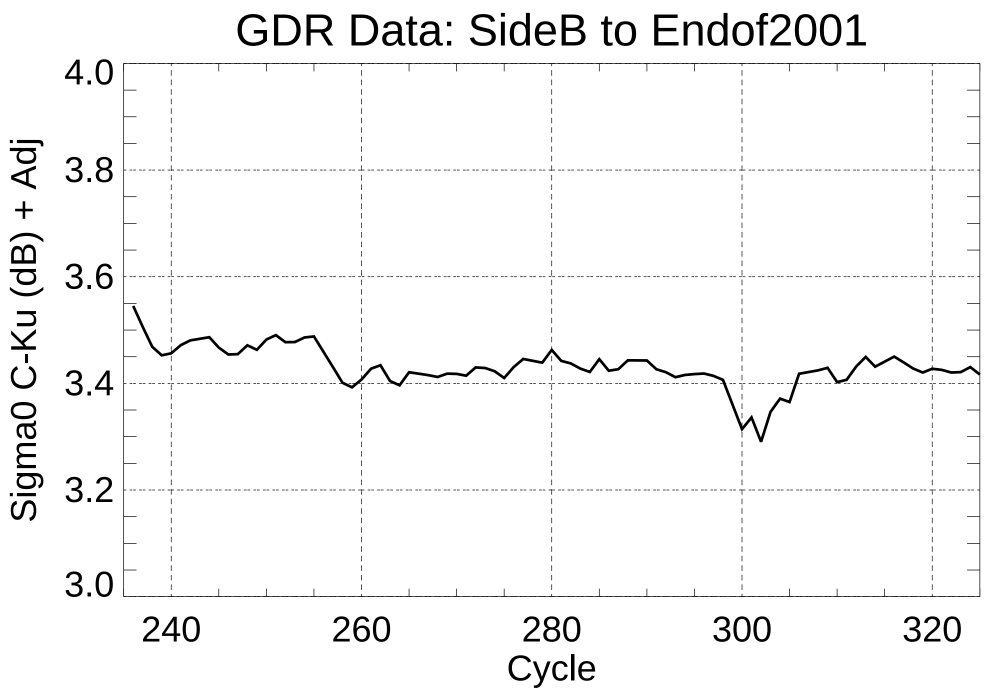


Figure 4-5 Cycle-Average Sigma0 Delta in dB with Cal Table Adjustment

Section 5

Engineering Assessment Synopsis

5.1 Performance Overview

Side B of the NASA Radar Altimeter was turned on, for the first time in space, on February 11, 1999. This followed six-and-a-half years of very successful on-orbit operations by Side A. Side A was turned off due to its Point Target Response having changed slightly over time, affecting measurement consistency. Side B is now the operational altimeter; however, Side A could be turned back on if needed.

Side A performance significantly surpassed all it pre-launch specifications, including its length of service. Based on our performance analysis and based on the reports of science investigators, Side B is performing as well as, or perhaps even better than, Side A.

We are continuing our NASA Radar Altimeter performance assessment of Side B on a daily basis. We were pleased with the successful launch of Jason-1 on December 7, 2001 and look forward to assessing its performance. Some of the techniques we have used on the TOPEX NASA Altimeter will be applied to Jason-1 for limited amounts of data.

Section 6

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6.1 Supporting Documentation

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Appendix A
Accumulative Index of Studies

Side B Point Target Response - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2001,* June 2001.

Ancillary Performance Assessment Results, using the Differencing of the Ku-Band and C-Band Data - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2001*, June 2001.

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Assessment of the Cycle-by-Cycle TOPEX Altimeter Noise Level by High-Pass Filtering 1-Hz Data - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2001*, June 2001.

Land-to-Water Acquisition Times - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2001*, June 2001.

Attitude Anomaly - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2001*, June 2001.

Side B Point Target Response - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2000*, September 2000.

Land-to-Water Acquisition Times - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2000*, September 2000.

Transition to Side B - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2000*, September 2000.

Side A Point Target Response Changes and Consequences - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Launch to Turn-Off of Side A on February 10, 1999*, August 1999.

Launch-to-Date Internal Calibrations - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Launch to Turn-Off of Side A on February 10, 1999*, August 1999.

Launch-to-Date Cycle Summaries - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Launch to Turn-Off of Side A on February 10, 1999*, August 1999.

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Launch-to-Date Engineering Monitors - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Launch to Turn-Off of Side A on February 10, 1999*, August 1999.

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C-Band Power Drop - *TOPEX Radar Altimeter Engineering Assessment Report, Update: Launch to January 1, 1997*, March 1997.

Oscillator Drift Algorithm Change - *TOPEX Radar Altimeter Engineering Assessment Report, Update: Launch to January 1, 1997*, March 1997.

Seasonal Distribution of Sigma-0 Blooms - *TOPEX Radar Altimeter Engineering Assessment Report, Update: Launch to January 1, 1997*, March 1997.

Effects of Coastlines - *TOPEX Radar Altimeter Engineering Assessment Report, Update: Launch to January 1, 1997*, March 1997.

TOPEX Altimeter 1996d362t 12:55 Side B C MTU Transmit Anomaly - *TOPEX Radar Altimeter Engineering Assessment Report, Update: Launch to January 1, 1997*, March 1997.

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